PHYSIOLOGICAL ASPECTS OF IRON NUTRITION IN SUGARCANE

Thesis submitted in part fulfillment of the requirement
for the degree of DOCTOR OF PHILOSOPHY (AGRICULTURE) in
CROP PHYSIOLOGY to the TAMIL NADU AGRICULTURAL UNIVERSITY
Coimbatore - 641 003

By

M. ANTONY JOSEPH RAVI SAVERY
(I.D. No. 05-808-001)

DEPARTMENT OF CROP PHYSIOLOGY
CENTRE FOR SOIL AND CROP MANAGEMENT STUDIES
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE 641 003

2008

PHYSIOLOGICAL ASPECTS OF IRON NUTRITION IN SUGARCANE

By

M. ANTONY JOSEPH RAVI SAVERY

DEPARTMENT OF CROP PHYSIOLOGY
CENTRE FOR SOIL AND CROP MANAGEMENT STUDIES
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE 641 003

2008

CERTIFICATE

This is to certify that the thesis entitled **" PHYSIOLOGICAL ASPECTS OF IRON NUTRITION IN SUGARCANE"** submitted in part fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) IN CROP PHYSIOLOGY** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mr. M. ANTONY JOSEPH RAVI SAVERY** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles, prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Place: Coimbatore

(Dr. G.DHARMARAJ)

Date : Chairman

Approved by:

Chairman:

(Dr. G.DHARMARAJ)

Members :

(Dr. S.MOHANDASS)

(Dr. R.JAYAKUMAR)

(Dr.S.MANOHARAN)

Date: External Examiner:

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACKNOWLEDGEMENT

"The Lord is my strength and shield;
My heart trusted in him and I am helped"

I wish to express my heartfelt gratitude devotion and indebtedness to ***Dr.G.Dharmaraj****, Professor, Department of Crop Physiology, TNAU, Coimbatore, for his suggestions, meticulous guidance, cordial treatment, incessant inspiration and ever willing help throughout the progress of my Ph.D degree programme.*

I express my gratitude to the members of my advisory committee ***Dr.S.Mohandass****,Professor,CropPhysiology,WTC,TNAU,Coimatore,****Dr.R.Jayakumar****,Pr ofessor, Soil Science and Agricultural Chemistry, ARS, Bhavanisagar,and* ***Dr.S.Manoharan*** *, Professor, Department of Agronomy, TNAU, Coimatore for their keen interest with constructive criticism, valuable suggestions, guidance throughout the entire period of investigation.*

I place my sincere thanks to ***Dr.H.Vijayaragavan****, Professor and Head, Department of Crop Physiology, TNAU, Coimatore for his timely help and assistance with usage of available facilities.*

I thank ***Dr.K.Subburamu****, PG Co-ordinator, Department of Crop Physiology, TNAU, Coimatore for his constant encouragement, laudable counseling and exorbitant motivation throughout the period of study.*

I am extremely happy to place on record my deep sense of gratitude and profound etiquette, intrinsic affection and heartfelt thanks to ***Dr.S.Rakiyappan****, Principal Scientist and Head Soil Science and Agricultural Chemistry, Sugarcane Breeding Institute, Coimbatore -7 who treated me as a brother with great empathy and provided constructive suggestions and criticism which made me to carry out the research smoothly and successfully.*

My sincere thanks to all the ***staff members*** *of Department of Crop Physiology, TNAU, Coimbatore for their love and affection during the course of study.*

I am happy to convey my thanks to the ***non-teaching staffs*** *of the Department of Crop Physiology, TNAU, Coimbatore for their assistance during this period.*

*Words are insufficient to express my thanks to my **classmates, my senior's friends** and also **to my junior**s for their unfathomable help during the study.*

*Words cannot express what I owe to my **parents** and **family members** for their love, moral support, everlasting encouragement and prayers which made me to complete this thesis successfully.*

*I thank **Vignesh Computers** for their neat execution of this thesis preparation.*

ANTONY JOSEPH RAVI SAVERY

ABSTRACT

PHYSIOLOGICAL ASPECTS OF IRON NUTRITION IN SUGARCANE

BY

M. ANTONY JOSEPH RAVI SAVERY

Degree : DOCTOR OF PHILOSOPHY IN CROP PHYSIOLOGY

Chairman : **Dr. G. DHARMARAJ, Ph. D.,**
Professor of Crop Physiology
Tamil Nadu Agricultural University
Coimbatore – 641 003.

2008

Field experiments were conducted in the Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore during the main season (January planting) of 2007-2008 to study the impact of foliar application of micronutrients viz., iron, manganese, zinc and plant growth regulators viz., brassinolide and salicylic on morphological, physiological, biochemical, yield components and quality of sugarcane (cv. Co 86032).

The results revealed that the tillering capacity, shoot population, and single cane dry weight were significantly influenced by foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm Brasssinolide followed by foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$.

The growth attributes viz., LAI, LAD, CGR, RGR, NAR, SLA and SLW were favorably influenced by the foliar application of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide.

The chlorophyll fractions, total chlorophyll and a/b ratio, gas exchange parameters viz., net photosynthetic rate, stomatal conductance, transpiration rate chlorophyll fluorescence, SPAD index, soluble protein were also significantly influenced by foliar application of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide.

The cation exchange capacity of roots also significantly improved by foliar application of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide. The

antioxidant enzymes viz. catalase and peroxidase were also influenced by foliar feeding of 1 % $FeSO_4$.

The Fe / Mn ratio narrowed down by foliar application of 1% $FeSO_4$ which indicates that the plants fed with iron are healthy and devoid of chlorosis. Foliar feeding 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ significantly reduced the P/Fe ratios which indicates that application of $FeSO_4$ probably had stimulated the expression of active Fe which is required for the synthesis of chlorophyll and hence retained the healthy nature of the plants.

The yield components and the cane juice quality parameters were significantly influenced by foliar feeding of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide.

CHAPTER I

INTRODUCTION

Sugarcane (*Saccharaum officinarum* L. family Graminae) cultivated commercially in 12 m ha in both tropical and subtropical climate is one of the world's most important cash crops. It is the major source of sugar and sweeteners and is being cultivated in more than 120 countries extending between 36.7º N and 31.0º S latitude. Although intensive cultivation is confined only to 10º North and South of equator, Brazil, India and Cuba alone accounts for 2/3rd of the world total cane production. India occupies the second position (13.54 million metric tonnes) in terms of sugar production next to Brazil which produces 26.30 million metric tonnes in 2004 (Anonymous, 2005) and first in terms of sugar production The world sugar production during 2005- 2006 as estimated by FAO was 150.9 million metric tonnes of cane sugar and it constitutes around 75% of the total sugar yield.. In India Sugarcane is extensively grown in the states of Uttar Pradesh, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu.

The major cane growing regions in India lies in the sub-tropical belt comprising of Uttar Pradesh, Bihar, Punjab, Haryana which account for about 70 per cent of the total area and 50 per cent of the total production. However, the productivity of the sub-tropical India is much less than the tropics where cane yields has touched 180 t ha^{-1}.

During the last fifty years, sugarcane production and productivity have increased considerably. The yield per hectare of sugarcane has gone up from 40.5 in 1950-51 to 70.8 t ha^{-1} in 2000-01.

The average yield of sugarcane in the country is 65 t ha^{-1} and 236.17 m mt was produced in the India during the year 2004-05 and 60 per cent of which is used for sugar production, while the rest is utilized for production of other sweeteners like jaggery and Khandsari.

The current requirement of sugar is about 18 m mt and the demand is expected to grow upto 22.74 m mt by 2012 AD.

Nowadays, great emphasis is laid on the importance of adequate supply of micronutrients in proper proportion for efficient utilization by crops. Micronutrients, though required in very small quantities by crops, are equally essential as that of the major and secondary nutrients for the normal growth of the crops. Among the several micronutrients, iron is regarded as the most important nutrition for sugarcane. Though this element is present in abundance in the soil, yet sugarcane suffers on account of its poor availability. The soils of Tamil Nadu which represents the tropical arid climate are mostly associated with calcium carbonate (Anon, 1973). Presence of high Calcium carbonate in the soils induces iron chlorosis in sugarcane as a result of reduction in the availability of soil iron besides considerable decline in the metabolically active iron in the soil and disturbed balance of iron and manganese in the tissue during later stages of growth (Anon, 1984). Iron chlorosis is more frequently noted in sugarcane crop than the other crops due to high removal of iron by this crop (Rakkiyappan, 1987).

Occurrence of iron deficiency in the soils leads to iron chlorosis and it has been recognized since 1844 (Gris, 1844) and was the first nutrient deficiency at that time. Sugarcane follows C_4 photosynthesis and the efficiency of energy conservation depends on the amount of chlorophyll present in the leaves. Iron deficiency affects plant growth and development which ultimately results in poor yield and quality of sugarcane. Because of iron chlorosis, the sugarcane crop sustains a loss to an extent of 74 per cent of cane weight and 41.7 per cent in sucrose content and 20.7 per cent in purity co-efficient of juice (Singh, 1973).

The efficiency of utilization of micronutrients is said to be increased by foliar application of micronutrients. Further application of growth regulators has been found to influence the cane yield and improve the juice quality characteristics in sugarcane. Brasssinolide regulates various physiological responses like cell division, cell elongation, synthesis of nucleic acids and proteins and enhancement of yield in cereals and vegetables. Application of salicylic acid to red gram during branching and flower bud initiation stages increased the number of flowers, pods and seeds per plant and seed yield

(Gurbaksh Singh *et al.,* 1980). In addition, spray of Salicylic acid on mung bean significantly increased the pod number per plant and yield (Gurbaksh Singh and Kaur, 1981).

With this background the present study was undertaken to evaluate the physiological role of micronutrients viz., iron, manganese and zinc in combination with Brassinolides and Salicylic acid on the yield and quality of sugarcane variety Co 86032 with the following objectives:

1. To alleviate iron chlorosis through foliar spray of micronutrients.

2. To study the combined effect of micronutrients/ PGRs on growth, cane yield and juice quality, and

3. To elucidate the physiological and biochemical mechanism for treatment variation and to study the utilization efficiency of iron with respect to yield and juice quality in sugarcane.

CHAPTER II

REVIEW OF LITERATURE

Micronutrients play important role in the growth and development of sugarcane crop. Though required in small amounts, micronutrients control most of the physiological activities of the crop by interrupting the level of chlorophyll content in the leaves which ultimately influence the photosynthetic activity of the plant. Micronutrients also play due role in the absorption and translocation of major nutrients like N, P and K. A brief review of the relevant literature on the requirement of micronutrients to sugarcane crop is given below.

2.1 Essentiality of iron to crops

Iron is essential for chlorophyll synthesis. Many workers reported close correlation between iron and chlorophyll in plants (Marsh *et al*., 1963; Terry and Low, 1982). Agarwala *et al.*, (1965) studied the effect of iron supply on nitrogen metabolism, biosynthesis of chlorophyll, enzymes and absorption of nutrients. According to them iron was reported to play a major role in the synthesis of precursor of chlorophyll. Iron also played a vital role in the synthesis of iron enzymes such as catalase, peroxidase and cytochrome oxidase. Many of the reactions associated with iron were the redox reactions of chloroplast, mitochondria and peroxisomes (Prince, 1968). These reactions included coupled electron transfer reaction (cytochrome a and b oxidase) (cytochrome oxidase) and peroxisomes (catalase and peroxidase) (Clarkeson and Hanson, 1980). Miller *et al*. (1982) indicated the vital role of iron in the formation of aminolevulinic acid the precursor of chlorophyll. When iron became limiting, thylakoid development slowed or stopped them, as the leaf continued to expand, the thylakoid constitutes such as iron and several types of chlorophyll were diluted, resulting in pale yellow colour, typical of iron deficiency. Iron was considered to be very essential for normal growth of crop. It played an important role in oxidation and reduction of nitrates and sulphates and essential for synthesis of protein in chlorophyll (Zende, 1979).

2.2 Levels of iron in sugarcane

The iron content varied in different parts of cane crop with age. Healthy sugarcane crop contained 100- 600 ppm of iron in the 3-6 leaf blades and the visual deficiency symptoms occurred when it decreased below 20 ppm. If the content exceeded 600 ppm it would be toxic to the cane crop (Singh, 1972 and Zende, 1979). According to Laksmikantham (1975), the iron content of 3 to 6 leaf ranged between 206 to 282 ppm. The quantity of iron present in a metric ton of millable cane was approximately 0.18 kg. Rao (1978) pointed out that iron content in the index leaves of C0 419 ranged from 127 to 187 ppm. The general range of iron in leaf blades was 30 to 206 ppm and in leaf sheath it was 40- 188 ppm (Sharma and Rao, 1978).Reddy *et al. (*1985) stated that the iron content of sugarcane grown at Agricultural Research Station, Rudrur ranged from 40-180 ppm in leaves and 100-300 ppm in sheath. Rao and Rao (1988) reported that the iron content of sugarcane leaf blades ranged from 84. 0 to 180.0 and 189.4 to 345.8 ppm in main and ratoon crops respectively. Sen and Samad (1975) indicated that the iron content in leaf and sheath tissues was increased due to increase in availability of iron under reduced soil conditions due to water logging .A negative relationship between leaf iron and age of the crop was observed till 300 days (Lakshmikantham, 1975).

2.3 Critical level of iron

Critical level is the optimum quantities of nutrient element required for healthy growth of crops.

Sharma and Rao (1978) suggested that screening of different cane tissues for iron content appeared to give more clear idea in ascertaining critical level of iron in the cane crop. It was also essential to understand more about trace element levels in cane with respect to properties of soil in which they were grown. Owing to multiple and complex interactions known to occur among nutrients, it could be always better to correlate critical level of iron with threshold values of nutrients of the same sample. The critical level of iron in soil depended upon the nature of extractant, its pH, soil texture, various chemical reactions in soil and the chemical properties of soil (Trierweiler and Lindsay, 1969). Other factors important in the fixing up of critical level were age at sampling

(Clements,1964 and Brown,1975), interactions with other nutrients (Evans *et al*., 1956 and Brown, 1973) and varietal or cultivar differences (Brown, 1975).

According to Olsen and Carlson (1950) the critical level of iron was 2 ppm which was extractable by N NH_4OAc (pH 4.8). Schmehl and Humbert (1964) stated that 5.0 ppm of iron was the critical concentration in 3, 4, 5 and 6 leaf blades of sugarcane. Evans (1965) suggested that 5.0 ppm of iron in top visible dewlap leaf of sugarcane was the critical limit. Misra and Pande (1974) fixed 2.5 to 4.5 ppm as the critical limit for iron in soils. Rajagopal *et al*. (1975) fixed 2 ppm of available iron as the critical limit for Tamil Nadu soils. Rao (1978) and Zende (1979) suggested that 4.00 ppm of iron was the critical limit using DTPA extractant and 5.0 ppm of iron in leaf as critical limit below which chlorosis occurred.

Halvin and Soltanpour (1981) established that the critical level of iron in soil for sorghum was 4.8 ppm using NH_4HCO_3 – DTPA extractant. Kumaresan *et al*. (1988) suggested that 3.7 ppm was the critical level for Tamil Nadu soils and 10 ppm of iron in sheath of elongating leaves as the critical limit for sugarcane crop. Rao and Rao (1988) fixed 4.0 ppm of iron as the critical limit for Andhra Pradesh soils. Tamilmani (1983) fixed 5.0 ppm of iron as the critical limit using 0.005 M DTPA (pH 7.3) for sorghum crop grown in calcareous soils of Coimbatore district. Yadav and Yaduvanshi (1989) stated that the critical level could be more than 10 mg Kg^{-1} if Fe / Mn ratio was more than 1.0 in 3 to 6 leaf blades of sugarcane. Ramadass and Devarajan (1991) found 6.1 ppm as the critical level of iron for sorghum crop in calcareous soils of Coimbatore District in Tamil Nadu.

2.4 Causative factors for iron chlorosis

Humbert and Martin (1955) reported that Fe / Mn ratio of less than 15:1 to be highly conducive for iron chlorosis indicating insuffiency of iron due to unbalanced ratio between these two elements. Patil *et al*. (1956) were of the opinion that chlorosis was caused due to deficiency of iron in the soil having high $CaCO_3$ content. Evans (1959) also reported that high HCO_3 uptake rendered iron unavailable for synthesis of chlorophyll at active sites. Khatri and Singh (1973) observed that it was not the level of iron in the soil

which had the controlling factor but the availability of that element to the plants for its proper utilization played vital role after chlorosis. Singh *et al.* (1974) stated that iron chlorosis was found to be linked with poor aeration, high Mn content and excess of application of P. Tandon and Srivastava (1978) while reviewing the causes for chlorosis, mentioned that presence of HCO_3 in the soil produced due to the hydrolysis of $CaCO_3$ was indirect cause for iron chlorosis. They further observed that the uptake of iron was not affected by the presence of high HCO_3 levels but being made unavailable at the active sites for metabolic purposes by higher HCO_3 uptake. Fogliata and Bustos (1980) were of the opinion that $CaCO_3$ ranging from 1.5 to 2.0 per cent in the soil was found to cause chlorosis and became more severe at 3 per cent. Naidu *et al.* (1980) reported that high P concentration in the nutrient medium reduced the availability of iron. Tandon and Srivastava (1981) reported that chlorotic plants grown in black soil contained higher amounts of iron and lower amounts of Mn. The inactivation of iron in chlorotic leaves might be associated with mineral nutrition imbalance like high P/ Fe ratio. The foliar application of $FeSO_4$ brought the disturbed ratio of P/Fe, K/Fe and K/Ca ions to normal levels and probably stimulated the expression of active Fe for synthesis of chlorophyll (Joshi and Naik, 1981).

Ramanathan *et al*., (1987) found that the soil with free $CaCO_3$ content more than 8.3 ± 4.5 per cent, DTPA Fe content less than 5.43 ± 0.86 ppm, DTPA Zn content of more than 0.99 ± 0.1 ppm, EC of 0.32 m mhos cm^{-1} and a high level of HCO_3 (12.5 – 14.0 me $litre^{-1}$) and low level of Ca in the irrigation water all collectively contributed to cane chlorosis. Yadav and Singh (1988) observed that the presence of $CaCO_3$, HCO_3, Ca and imbalance of nutrient cations in the growth medium, injudicious addition of phosphate and quality of irrigation water had been held responsible for chlorosis. Somavanshi and Kadu (1988) found that the high soil organic carbon and Mg/Ca ratio seemed to be associated with chlorosis in sugarcane. Velu (1989a) reported that the soil having more than 8.1± 4.5 per cent $CaCO_3$ could be expected to show chlorosis. Pal *et al*. (1990) suggested the iron deficiency was caused by the combined effect of active $CaCO_3$, low iron levels of more than 4.5 ppm DTPA extractable iron in soils and inactivation of Fe in leaves.

2.5 Correction of iron chlorosis in sugarcane

Patil *et al*. (1956) recorded that spraying of 0.5 per cent $FeSO_4$ solution resulted in restoring the green colour of the chlorotic plants. Tomar *et al*. (1965) found that spraying of 3 % $FeSO_4$ per cent would result in quick and complete recovery of chlorosis and plants resumed their normal activities and vigor but with 2 % spray treatment the recovering effect was comparatively less. Singh (1972) suggested foliar application of $FeSO_4$ + $MnSO_4$ + Urea for rapid recovery of the plants. Singh and Singh (1973) reported that application of Fe alone or in combination with Mn and N as foliar spray caused favorable influence on the recovery of the chlorosis. Applications at fortnightly intervals of 2 % $FeSO_4$ were found to avoid chlorosis (Lakshmikanthan, 1975).Restoration of green colour in sugarcane leaves was noticed by Goyal and Tyagi (1976) by spray of $FeSO_4$ with citric acid. Garg and Agarwal (1976) suggested that chlorotic conditions could be corrected by spraying of 2 % $FeSO_4$. For obtaining better results, it was suggested to mix a solution of 0.5 % $MnSO_4$ and 2.0 % urea along with $FeSO_4$.

Srivastava *et al*. (1978) showed that application of 250 kg ha^{-1} low grade pyrites could be used for correcting the chlorosis. Naidu *et al* (1980) suggested the judicious application of phosphatic fertilizer and green manuring as supplementary measures in addition to spray application of $FeSO_4$ to overcome Fe chlorosis. Mathur and Talati. (1984) advocated foliar application of 0.5 to 3.0 % $FeSO_4$ solution with citric acid to correct iron chlorosis whereas 3.0 % had quick effect. Sharma and Kanwar, (1985) reported that iron foliar spray was highly effective to correct the chlorosis of young leaves.

Waraitch and Kanwar (1988) found that the recovery of chlorotic plants was observed to be the highest by foliar spray of iron with urea. Joshi *et al* (1989) reported that soil application of $FeSO_4$ in conjunction with 100 Kg farm yard manure or green manuring crop 8-10 tonnes ha^{-1} as green matter was found to be effective to control chlorosis. Ramanathan *et al.* (1987) advocated that 1.0 per cent $FeSO_4$ foliar spray could be given at 45^{th} and 90^{th} day after planting to correct iron chlorosis. Pal *et al*. (1990) found that foliar spray of 2.5 % $FeSO_4$ resulted in greening of chlorotic

leaves. Rakkiyappan (1993) stated that $FeSO_4$ 1% foliar spray at weekly intervals (four times) alleviated the chlorosis and improved the sugarcane crop growth.

2.6 Relationship of iron with other major nutrients

Brown (1961) pointed out that high phosphate content in soil was one of the factors that decreased the availability of Fe. The P/Fe ratio was a useful index to asses the status of Fe in plants (Odurukwe and Maynard, 1969).Woods and Nolan (1968) stated that addition of Fe as $FeSO_4$ to soils had no effect on soil pH, N, P and K contents of soil.

Dev and Mann (1972) stated that addition of phosphate to soil decreased the availability of iron. Similar observation was made by several workers (Juang, 1976; Mani and Mayalagu, 1986; Rao, 1989).Chandrasekaran (1976) reported a negative association between available K and available Fe. Velu (1977) found that soil application of Fe depressed the available P and K in the soil. Wallace and Muller (1980) reported that N promoted Fe uptake in calcareous loamy soil, when Fe was added as a chelate. Excess calcium induced the Fe deficiency (Rao, 1989).

2.7 Relationship of iron with other micronutrients

Iron deficiency is commonly induced by excess levels of other trace elements, both singly and more commonly in various combinations (Brown, 1961, and Wallace *et al.*, 1992).

Gupta *et al*. (1970) observed a negative correlation between available Cu and Fe in saline and sodic soils of Madhya Pradesh. Juang and Chang (1973) observed a significant antagonistic effect of Zn and Fe on growth and yield of sugarcane. Venkatasubramanyam and Mehta (1975) found that application of Zn decreased the availability of Fe and increased that of Mn while addition of Fe decreased the availability of Zn in the soil. Juang (1976) reported that antagonistic effect of Zn and Fe where the uptake of Zn was inversely related to uptake of Fe. Rakkiyappan (1986) reported that the available Fe and Mn showed significant negative association with $CaCO_3$ content. When available Fe in soil was low, it was possible to induce Fe deficiency with application of Zn (Muralidharadu and Singh, 1990). The deficiency of Fe was found to be linked with

high Mn content (Singh *et al*., 1974; Rao, 1989).There was a negative interaction between Zn and Fe in soil (Rao, 1989). Warden and Reisenwear (1991) reported that Fe and Mn uptake was positively interrelated because both Mn and Fe were mobilized by similar root processes. The available Fe was positively and significantly correlated with available Mn and Cu (Sangwan and Singh, 1993).

2.8 Effect of iron, manganese and zinc and brassinolides on the morphological characters

2.8.1 Germination

Sett germination in sugarcane is by and large governed by age of the seed cane, environmental factors particularly temperature, relative humidity and soil moisture. In addition germination is also controlled by the availability of nutrients such as glucose, moisture present in the sett. According to van Dillewijn (1952), the absorption of nutrients from the soil is made only after the permanent shoot root system is made functional and develops only after 35 days i.e. after the completion of germination. Mathur B.S (1975) reported that application of Spartin (Fe – 5200 ppm + Mn – 4700 ppm + Zn – 1600 ppm) at the rate of 500 kg / ha in addition to normal fertilization of the cane crop resulted in marginal increase in tiller production by 5.7 per cent where as increase in germination per cent and millable canes/ha was small *i.e*. 0.4 and 0.9 per cent.

2.8.2 Tiller number

Tillering capacity is an important character in sugarcane as it is directly related to final millable cane production at harvest. Tillering in sugarcane is a genetic character. However, several studies have indicated that it could be altered to a certain extent by environmental factors such as soil moisture, nutritional status and cultural techniques besides atmospheric temperature (Clements, 1980). A considerable increase in size and number of yield contributing parameters like number tillers per stool, millable canes, plant height, length and girth of internodes and chlorophyll content of sugarcane with the application of micronutrient *viz*. Fe, Cu, Mn, and B.(Anon., 1983). Nayyar *et al*. (1984) studied the response of sugarcane to Zn and Fe sources and reported that all the yield contributing characters *viz.* number of tillers, millable canes per stool, cane yield of

sugarcane and reported that Zinc in combination with N and P increased all the characters i.e. number of tillers per stool, plant height, number of internodes per plant, leaf area, cane brix percentage, pol percentage, CCS percentage, and sugar yield. Yadav *et al*. (1987) reported that foliar application of ferrous sulphate, manganese sulphate, zinc sulphate and copper sulphate improved the morphological characters. Increased tillering capacity due to foliar feeding of zinc sulphate was also reported by Kumaresan *et al*. (1989). Foliar application of 1.0 per cent ferrous sulphate at 45 and 55 days after sowing increased the tiller per plant in ginger (Singh and Dwivedi, 2007).

2.8.3 Shoot population

Shoot population is an important character in sugarcane which is directly correlated with the cane yield. Anon (1983) reported a considerable increase in size and yield attributing characters *viz*., tillers per stool, shoot population, plant height, length and girth of internodes with application of micronutrients of Fe, Cu, Mn and B. Jayabal *et al*. (1991) reported improvement in shoot population due to application of zinc sulphate. Wang *et al*. (2005) also reported 12 per cent increase in shoot population with foliar application of zinc sulphate.

2.8.4 Single cane dry weight

Application of iron resulted in the formation of chlorophyll and helped in increased photosynthetic activity and accumulation of dry matter especially the green foliage of the plants (Sen and Samad, 1975). Dwivedi and Singh (1991) also reported similar increase in dry matter production by foliar application of iron.

2.9 Effect of iron, manganese and zinc and brassinolides on the growth attributes

2.9.1 Leaf Area Index

The canopy photosynthesis largely depends on the Leaf Area Index (LAI) and canopy structure which in turn contributes to dry matter production. Kanagaraj *et al.* (1981) reported increase in green leaf surface area due to foliar spray of $FeSO_4$. Reddi Ramu *et al.* (2007) reported an increase in leaf area index in maize due to foliar application of zinc sulphate. Exogenous application of Brassinolide increased

morphological and growth parameters like leaf area, number of leaves, plant height, Specific Leaf Weight (SLW), Crop Growth Rate (CGR), and Relative Growth Rate (RGR) (Prakash *et al.*, 2007). Kumavat *et al*. (2005) reported that basal application of 25.0 and 12.5 kg ha^{-1} ferrous sulphate at 20 DAS significantly increased all the physiological parameters viz. LAI, CGR, NAR and SLW. At 40 DAS and maturity, both basal application as well as foliar application of 0.5 % $FeSO_4$ + citric acid at preflowering and both at preflowering and flowering was found to be significantly better over control in summer green gram. Bindu (2000) observed that application of brassinolide markedly increased the leaf area index in ground nut.Brassinolide promoted the leaf area accompanied by the increased leaf number and the enhancement of leaf area index (Kelaiya *et al.*,1991). Nawalgatte and Panchal (1991) reported increase in leaf area index in ground nut.

2.9.2 Leaf Area Duration

Leaf Area Duration (LAD) signifies photosynthetically active period of the leaf. It is a measure of duration of photosynthetic apparatus upto which it can accumulate the dry matter for growth and development (Wetblank *et al*., 1966). Soil application of zinc sulphate @ 10 kg ha^{-1} recorded significantly higher LAD in wheat (Kumar *et al.*, 2004). The beneficial role of brassinolide in prolonging the LAD in sesame was explained by Prakash *et al*. (2007).

2.9.3 Net Assimilation Rate

Net Assimilation Rate (NAR) is considered as important plant trait, which contributes for crop growth rate (Gregory, 1926). Watson (1958) confirmed the dependence of NAR on LAI. Theodor *et al.* (2005) reported an increase in CO_2 uptake, chlorophyll content and NAR in Poplar due to soil application of iron as iron chelates. Pandya *et al*. (2004) reported increased NAR after addition of 0.05 per cent manganese solution to the barley seedlings grown under salt stressed conditions in poly bags. Increased NAR by foliar application of 0.5 % ferrous sulphate at preflowering and both at preflowering and flowering stages was reported by Kumavat *et al*. (2005) in green gram.

2.9.4 Relative Growth Rate

Relative Growth Rate (RGR) is an index of the amount of growing material per unit dry weight of the plant. Cramer and Nowak (1992) found a linkage between manganese, photosynthesis and growth of barley plants. They propounded the hypothesis that a linkage between manganese concentration in shoot and RGR appeared to be through the effects of manganese nutrition on photosynthesis. Pandya *et al*. (2004) reported increased RGR after addition of 0.05 per cent manganese solution to the barley seedlings grown under salt stressed conditions in poly bags. Prakash *et al*.(2007) reported foliar application of 0.5 ml/L brassinolide thrice i.e., on 30, 45 and 60 DAS recorded higher values of growth parameters like plant height, number of branches, and number of leaves, specific leaf weight, crop growth rate, net assimilation rate and relative growth rate contributing to higher dry matter production.

2.9.5 Crop Growth Rate

Crop Growth Rate (CGR) is considered as the efficiency of the crop to accumulate biomass per unit land area. Yadav (1998) reported improvement in all the growth parameters viz., CGR, LAI, NAR, and dry matter at all the stages of growth in green gram due to foliar feeding of iron as ferrous sulphate. Prakash *et al*. (2007) reported foliar application 0.5 ml/L brassinolide thrice i.e., on 30, 45 and 60 DAS recorded higher values of growth parameters like plant height, number of branches, and number of leaves, SLW, CGR, NAR and RGR contributing to higher dry matter production. Umadevi (1988) and Bindu (2000) reported that application of brassinolides increased the CGR in both sesame and groundnut.

2.9.6 Specific Leaf Area

The Specific Leaf Area (SLA) reflects the thickness of the leaf and relative proportion of conductive tissues. Yadav (1998) reported that application of iron significantly increased dry weight of root nodules, CGR, LAI, NAR and dry matter accumulation at all stages of green gram growth.

2.9.7 Specific Leaf Weight

Specific Leaf Weight (SLW) indicates the quantity of metabolites accumulated per unit leaf area. Kumavat *et al*. (2005) reported that basal application of 25.0 and 12.5 kg ha^{-1} ferrous sulphate at 20 DAS significantly increased all the physiological parameters viz. LAI, CGR, NAR and SLW. Prakash *et al*. (2007) reported foliar application 0.5 ml/L brassinolide thrice i.e., on 30, 45 and 60 DAS recorded higher values of growth parameters like plant height, number of branches, and number of leaves, SLW, CGR, NAR and RGR contributing to higher dry matter production. Braun and Wild (1984) observed that foliar application of brassinolide increased the thickness of the 3rd leaf in wheat. Kumaran and Subramanian (2001) reported that foliar feeding of 1% di-ammonium phosphate, 0.5% urea, 0.5 % magnesium sulphate and 0.25 % zinc sulphate increased the SLW in black gram.

2.10 Effect of iron, manganese and zinc and brassinolides on the physiological / biochemical parameters

2.10.1 Chlorophyll content

Chlorophyll plays an important role in the photosynthesis (Kadam *et al*., 1988). Gris (1943) was perhaps the first to point out the essentiality of iron for the maintenance of chlorophyll in plants. Naik and Joshi (1974) reported that foliar spray of 0.5 % ferrous sulphate changed the chlorophyll content in sugarcane variety Co 740. After three months of spray there was a significant increase in the total chlorophyll content. Kudachikar *et al*. (1992) reported an increase in metabolic iron and total chlorophyll content in sugarcane variety Co 740 with 2 per cent $FeSO_4$ foliar spray. Mehrotra *et al*.(1990) reported an increase in chlorophyll content in maize with foliar spray of iron as ferric ethylenediamine tetra acetate Increased chlorophyll content by foliar application of manganese has been reported due to enrichment of ultra structure of the thylakoids as a consequence of promotion of carotenoid biosynthesis (Polle *et al.*, 1992). Higher chlorophyll content might be due to the involvement of zinc in the biosynthesis of this pigment (Beale, 1999). Zinc is known to catalyze the condensation of two molecules of α-aminolevulinic acid to form porphobilinogen (Jaffe, 1995) which is ultimately responsible for the protoporphyrin formation, a precursor for chlorophyll biosynthesis. Tripathy *et al*. (1999) reported increased chlorophyll content in soybean is

due to zinc application through zinc sulphate and indicated that sulphur from zinc might have helped for the biosynthesis of chlorophyll. Mohamed Amanullah *et al*. (2007) reported that foliar spray of 2 % ferrous sulphate recorded 1.62 and 1.63 mg/g of chlorophyll content in sole and intercropping system of sorghum. Kulaeva *et al*. (1991) reported that brassinolide induced increase in chlorophyll content in plants which could be attributed to increase in enzyme protein. Similar results were obtained in mung bean by foliar application of brassinolide which may be attributed to several factors including inhibition of senescence and enhanced uptake of iron (Bhatia and Kaur, 1997).

2.10.2 SPAD index

The SPAD index indicates the amount of chlorophyll in the leaves quantitatively. The increase in SPAD index, which is an indirect measure of chlorophyll status is attributed to the increase in the chlorophyll fractions due to the role played by iron (Bhatia and Kaur,1997), manganese (Dube *et al.,* 2001), zinc (Beale,1999) and brassinolide (Kulaeva *et al.,* 1991) in chlorophyll biosynthesis. Ranferi Maldonado – Torres *et al*. (2006) observed that SPAD index decreased as severity of iron chlorosis increased. Ana Álvarez-Fernández *et al*. (2005) observed that the plant characteristic most affected by iron chlorosis was the leaf SPAD index that markedly increased in iron-treated plants and decreased in control plants. Reyes *et al*. (2006) reported that the leaf chlorophyll concentration (estimated as SPAD index by Minolta SPAD – 502 chlorophyll meter) was positively correlated with the contents in different soil iron forms but not with alkalinity-related soil properties (pH, calcium carbonate equivalent, and active lime).

2.10.3 Chlorophyll fluorescence

The chlorophyll fluorescence allows studying the different functional levels of photosynthesis indirectly. Loss of excess energy absorbed by the chlorophyll molecules in a number of ways, such as light, heat and re-emission is known as fluorescence. Chlorophyll fluorescence ratio F_{735}/ F_{700} was linearly proportional to the chlorophyll content in beech, elm and wild vine (Gitelson *et al*., 1999). James A. Guikema (1985) working in cyanobacteria *Anacystis nidulans* reported a rise Fv/Fm ratio due to supply of iron as ferric ammonium citrate in the culture medium.

James C. Pushnik *et al*. (1989) working in tobacco reported an increase in fluorescence yield with foliar treatment of $FeSO_4$ at 250 ppm. Jing Quan Yu *et al*. (2004) also stated that brassinolide treatment in *Cucumis sativus* resulted in large increase in the chlorophyll fluorescence and photosynthetic capacity and of leaves.

2.10.4 Photosynthetic rate

Photosynthetic efficiency is the primary component of dry matter accumulation. Green house experiments were conducted in maize plants by Nenova *et al*. (1993) who reported a decrease in the photosynthetic rate per leaf area under iron deficit conditions (0.75 mg Fe/L) whereas supply of optimum levels of iron (7.5 mg Fe/L) increased the photosynthetic rate. Arulanatham *et al.* (1990) reported that foliar application of ferrous sulphate increased the activity of stroma enzymes such as RuBisCO and ferredoxin content. Seethambaram *et al.* (1985) working in rice and ragi plants reported that zinc supply increased the net photosynthetic rate due to increased levels of energy. Jing Quan Yu *et al*. (2004) also stated that brassinolide treatment in *Cucumis sativus* resulted in large increase in the photosynthetic capacity of leaves.

2.10.5 Transpiration rate

Transpiration is the major process involving water loss from the plants through the stomata in the form of water vapor. DeKock *et al*. (1981) working in maize plants reported that iron deficiency increases the transpiration rate as a result of loss of stomatal control mechanisms. Kleinkopf *et al*. (1976) working in iron deficient soybean reported an increase in transpiration under iron deficiency.

2.10.6. Stomatal conductance

Stomatal conductance is the measure of ability of the plant to allow for gaseous exchange from the external environment. Foliar application of 20 µM Fe-EDDHA as iron source increased the net photosynthetic rate and stomatal conductance in citrus. Terry (1984) reported a decrease in stomatal conductance in sugar beet under iron deficiency. Vassilios Chouliaras *et al*. (2004) reported higher net photosynthetic rate and stomatal conductance with foliar application of 20 µM Fe-EDDHA as iron source in citrus.

2.10.7 Soluble protein

Soluble protein content in leaf is an indicator of the RUBP case activity which occupied nearly 60 to 70 per cent of this abundant protein in the plants (Evans, 1982). Del Rio *et al*. (1978) working in pea plants under green house conditions reported that supply of iron at 30 ppm to the nutrient solutions recorded an increase in soluble protein. Sairam (1994) reported that application of 0.1 ppm homobrassinolide increased the soluble protein content in wheat plants. Vardhini and Rao (1998) also reported that foliar spray of 1.0 µM brassinolide resulted in substantial increase in nucleic acids and soluble protein level in ground nut. Bindu (2000) reported significant increase in RNA and DNA polymerase activity and the synthesis of RNA, DNA and protein in groundnut due to foliar application of 0.1 ppm brassinolide.

2.10.8 Cation Exchange Capacity

The importance of root Cation Exchange Capacity (CEC) in mineral uptake of field crops has been emphasized by several workers (Palliwal and Subramanian, 1964; Singh and Ram, 1973; Chhabda *et al*., 1980; Rao and Narasimham, 1990). Jat and Mehra, 2007 reported that foliar application of sulphur and zinc improved the CEC of the roots of mustard and thereby increased the nutrient absorption. Cinelli *et al*.(1985) working in rootstocks of *Prunus cerasifera* L. reported that in iron efficient roots the CEC was markedly increased and it could be used as a predictive marker of lime-induced chlorosis tolerance.

2.10.9 Catalase

Catalase is an antioxidizing agent and scavenging enzyme which protects the crops from damage caused by the accumulation of free radicals (Casano *et al*., 1999). Kaur *et al*. (1984) reported that foliar application of 0.5 % ferrous sulphate restored the activity of catalase in slightly and moderately chlorotic genotypes of peas. He further reported 50 per cent increased catalase activity in the genotypes of *Cicer arietinum* due to foliar application of 0.5 % $FeSO_4$ than in unsprayed control. Del Rio *et al*. (1978) reported foliar application of 2.5 ppm Fe-EDDHA as iron source to pea plants increased the catalase enzyme activity. Application of 2 per cent $FeSO_4$ to chlorotic sugarcane

(cv.Co 740) caused a recovery from chlorosis possibly due to increases in metabolic iron and increased catalase activity (Kudachikar *et al*., 1992). Leidi *et al*. (1986) reported increased catalase activity in soybean plants grown in petri plates treated with 2.5 ppm Fe-EDDHA as iron source .Shyamananda Pattanaik (1950) reported increased catalase activity in rice seedlings grown in nutrient solutions containing manganese chloride upto 10 ppm. Anuradha and Seetha Ram Rao, 2007 reported an increased catalase activity in radish seedlings grown in nutrient solution containing 2 mM 24-epibrassinolide under lead stress.

2.10.10 Peroxidase

Peroxidase is also an antioxidant enzyme involved in scavenging of H_2O_2 (Shigeoka *et al*., 2002) and also involved in metamorphogenesis and auxin oxidation. Del Rio *et al*. (1978) reported foliar application of pea plants with 30 ppm Fe-EDDHA as iron source increased the peroxidase enzyme activity at 15 days and at 45 days growth periods. Foliar spray of *Cicer arietinum* genotypes with 0.5 % $FeSO_4$ at 60, 75, 90 and 105 days after sowing resulted in an increased peroxidase enzyme activity (Kaur *et al*., 1984). Mehrotra *et al*. (1990) reported that highest activity of peroxidase in maize plants grown in sand cultures treatment with 11.2 ppm Fe- EDTA. Leidi *et al*. (1986) reported an increased peroxidase enzyme activity in soybean plants grown in petri plates treated with $MnSO_4$ at 5 ppm. Jain *et al*. (2003) reported that peroxidase and catalase could be used as a biochemical marker for diagnosing field chlorosis in sugarcane.

Vassilios Chouliaras *et al*. (2004) reported that that citrus seedlings grown in poly bags supplied with 20 mM Fe-EDDHA recorded highest activities of enzymes catalase and peroxidase. Anuradha and Seetha Ram Rao, 2007 reported an increased peroxidase activity in radish seedlings grown in nutrient solution containing 2 mM 24-epibrassinolide under lead stress. Increased activity of catalase and peroxidase were obtained in sesame treated thrice with 0.5 mg/l of 28-epibrassinolide at 60 DAS (Prakash *et al*., 2007).

2.11 Effect of iron, manganese and zinc and brassinolides on the micronutrients content

2.11.1 Metabolically active iron

The metabolically active fraction of iron in plants has been considered as a correct estimate of true Fe status of the plant (Agarwala *et al*., 1976; Patel *et al*., 1977; and Takkar and Kaur, 1983). Soundarajan (1984) also observed an increase in the metabolically active iron in sorghum due to application of $FeSO_4$.

Chattopadhyay *et al*. (1989) opined that estimation orthophenanthrolene reactive iron could resolve the iron chlorosis in Japanese mint. Mehrotra *et al*. (1990) reported increase in chlorophyll, metabolically active iron and dry matter yield in maize following foliar feeding of 11.2 ppm Fe- EDTA as iron source. Kudachikar *et al*. (1992) observed higher metabolic iron at all stages of growth in sugarcane variety Co 740 with foliar spray of 2 % $FeSO_4$. Yerriswamy *et al*. (1994) also found a significant increase (nine times) in the concentration of metabolically active iron in fresh behaves of maize due to application of $FeSO_4$ while the increase in total iron was much less for the same treatment. Mohamed Amanullah *et al*. (2007) reported significant increase in metabolic active iron due to foliar spray 2 % $FeSO_4$ or as basal dose of 25 kg/ha $FeSO_4$ supplemented with foliar spray of 2 % FeSO4 in sole crop of sorghum or when intercropped with cowpea.

2.11.2 Fe / Mn ratio (Root and Soil)

It has been suggested that Fe / Mn ratio is a very good indicator of iron status of plant. Tandon and Srivastava (1981) studied the Fe / Mn ratio in healthy and chlorotic sugarcane plants of variety Co 678 and reported a wider Fe to Mn ratio in all the tissues of chlorotic plants whereas the ratio narrowed down in healthy plants. They further reported in their studies that wider Fe to Mn ratio was consistent in all the tissues of sugarcane and it can be taken as an index for diagnosing lime induced chlorosis.

2.11.3 P / Fe ratio (Root and Soil)

De Kock and Stremeeki (1954) pointed out that P / Fe ratio could serve as a better index of iron status of a plant than iron content. De Kock.(1955) stated that the ratio of phosphorus to iron is a critical factor in Fe nutrition of plants. He observed high values of about 60-70 in chlorotic leaves when compared to about 30 in healthy green leaves suggesting that the P/ Fe ratio may be used as a means of assessing the Fe status of

plants. The foliar application of $FeSO_4$ brings the disturbed ratio of P/ Fe of lower levels and probably stimulates the expression of active iron for synthesis of chlorophyll (Joshi and Naik, 1981). Abadia *et al*. (1985) recorded decreased P / Fe ratio when trunk injection of iron was given in peach trees. Tong Yue *et al*. (1987) observed that lower visual chlorosis contained slightly higher foliar iron levels and lower leaf P levels. The chlorosis resistant soybean, 'Pioneer 1082', contained higher leaf iron and lower leaf P than the susceptible 'Corsoy'. This same pattern was noted in apples. *M. micromalus,* 'York' and 'Golden Delicious' had more Fe and less P than the more susceptible rootstocks. Ranferi Maldonado-Torres *et al*. (2006) reported that the severity of Fe chlorosis in Mexican lime leaves was associated with a significant increase in the concentrations of K, total Fe, Mn and P/Fe ratios.

2.12 Effect of iron, manganese and zinc and brassinolides on the yield parameters

2.12.1 Millable cane number, millable cane weight and height, girth, number, average length of internodes, cane yield and sugar yield

Number of millable cane, millable cane weight and height, girth, number and average length of internodes are all important yield attributing characters in sugarcane. The final output of sugarcane mainly depends on the above characteristics. Tonapy *et al*. (1965) applied $ZnSO_4$, $MnSO_4$, borax, $CuSO_4$ and $FeSO_4$ with third dose of manure at the rate of 2 Kg ha^{-1} to different sugarcane varieties as soil application and found that the treated plots generally increased the yield and quality of sugarcane. Zende (1968) reported that spray application of 1 per cent $MnSO_4$ or dipping of cane setts in 1 per cent $MnSO_4$ before planting showed a better performance on cane height, girth and yield in addition to juice quality characteristics. Singh and Lallan Singh (1973) concluded from their studies conducted at shahjahanpur that foliar application of iron as 2 % $FeSO_4$ alone or in combination with Mn and nitrogen resulted in significant increase in cane height (22.3 %) cane weight (122.8 %) and marked improvement in juice quality viz., sucrose content (48.2 %) and purity coefficient of juice (16.3 %) over control.

Singh *et al.* (1974) observed that application of 20 ppm iron increased the cane yield by 10 t/ha based on the average values of four years. Agarwal and Lal (1987) found that application of 500 kg of pyrites ha^{-1} was good for increasing the millable canes and

cane yield. Altaf Ahmed *et al.* (1975) reported that application of Fe, Zn, Mg, Cu, Mn, B and Cl at 2.5 Kg per acre significantly increased cane yield by affecting millable canes per stool, plant height, length and girth of internodes, CCS per cent and sugar yield over control treatments. Marinho and Albuquerque (1981) reported that application of Cu and Zn increased the number of tillers per plant, number of millable canes, plant height, cane yield and sugar recovery of sugarcane crop over control. Anon (1983) reported a considerable increase in size and number of yield contributing parameters like number tillers per stool, millable canes, plant height, length and girth of internodes and chlorophyll content of sugarcane with the application of micronutrient viz. Fe, Cu, Mn, and B.

Nayyar *et al*. (1984) studied the response of sugarcane to Zn and Fe sources and reported that all the yield contributing characters viz. number of tillers, millable canes per stool, cane yield of sugarcane and reported that Zinc in combination with N and P increased all the characters i.e. number of tillers per stool, plant height, number of internodes per plant, leaf area, cane brix percentage, pol percentage, CCS percentage, and sugar yield except fibre percentage which showed a negative relationship with the applied elements. Rahman *et al*. (1986) studied the effects of Fe, Zn, Cu, and B on different growth parameters of sugarcane at three locations. They observed no significant effect of these elements on percent germination at any location. However, the number of millable canes, plant height, cane yield and CCS percentage were significantly increased at two locations. Shinde *et al*. (1986) studied the response of seasonal sugarcane to soil application of zinc in flood plains of Kolhapur region (Maharashtra) and reported that the application of zinc sulphate significantly affected the morphological characters (number of tillers per stool, millable canes per stool, plant height, stem diameter, leaf area, top weight, trash weight and cane yield) as well as the quality characters of sugarcane crop.

Yadav *et al*. (1987) analyzed data for the response of sugarcane to foliar application of micronutrients and reported that all the morphological characters were significantly improved with the foliar application of different micronutrients ($FeSO_4$, $ZnSO_4$, $CuSO_4$, and $MnSO_4$). $FeSO_4$ and $CuSO_4$ showed good effect on morphological traits while $ZnSO_4$ and $MnSO_4$ exhibited good effect on quality

characters. Kumaresan *et al*. (1985) conducted trials at seven locations with sugarcane cultivars and applied $ZnSO_4$ at 37.5 Kg. ha^{-1}, $FeSO_4$ at 100 kg. ha^{-1} and or press-mud at 5 tons ha^{-1} in different combinations in addition to N and P, K as basal dressing containing 275, 62.5 and 112 $kg.ha^{-1}$ of N, P_2O_5 and K_2O respectively. It was observed that B, Mn and Fe applied alone or in combination (Fe + Zn + Mn and Mn + B) significantly improved cane yield, CCS per cent, number of tillers per plant number of millable canes per stool, plant height, length and girth of internodes and sugar yield. They observed that micronutrients applied alone or in combination showed a positive correlation with all the parameters studied except the fiber percentage which showed a negative correlation with the applied micronutrients. Kumaresan *et al*. (1985) conducted experiments at five locations on micronutrient deficient soils of Tamil Nadu The treatment comprised of different levels of $ZnSO_4$ (0, 37.5, and 75.0 $kg.ha^{-1}$), $FeSO_4$ (0, 100, 200, 300 kg ha^{-1}) and $CuSO_4$ (0, 12.5 and 25.0 $kg.ha^{-1}$) were applied to soil and 0.5 % $ZnSO_4$ (or) 1 to 2% $FeSO_4$ were applied as foliar spray. The cvs tested were CoC 671 and CoC 8001. They reported that application of $ZnSO_4$ at 37.5 $kg.ha^{-1}$, $FeSO_4$ at 100 $kg.ha^{-1}$ and $CuSO_4$ at 12.5 $kg.ha^{-1}$ to the soil, increased the entire yield contributing parameters like number of tillers per plant, number of millable cane per stool, plant height, and number of internodes, length and girth of internodes. Yadav *et al*., (1987) and Kapur *et al*. (1988) observed that $FeSO_4$ application appeared to have improved the CCS % values. Palanivel (1990) conducted an experiment in an iron deficient calcareous soil, to study the effect of $FeSO_4$, $ZnSO_4$, and urea solution alone and in combination as foliar spray. He reported that combined foliar spray of 1.5% $FeSO_4$, 1% $ZnSO_4$, and 1% urea solution increased cane yield by 13 per cent over control followed by 11.5 and 9.8 per cent increase in yield by foliar spray of 1.5% $FeSO_4$ solution alone at fortnightly and monthly intervals over control. He further reported that application of all the nutrients significantly affected all the yield and yield components.

Bangar *et al*. (1991) reported that all the growth and yield contributory characters were benefited by the application of various levels of zinc and iron. The height of cane was reported to have increased significantly with increasing levels of iron and zinc. Naemet *et al*. (1992) found that application of 180 kg. N along with 33 g Zn gave the highest value of stalks diameter. It was also observed that application of

zinc fertilizers after 6 months from planting tended to increase significantly the diameter of sugarcane stalk. Banger and Sharma (1992) applied commercial formulations of micronutrients (Pushti, Agromin, Multiplex and Micron A) and single micronutrients [$FeSO_4$, $ZnSO_4$ and $MnSO_4$ and $CuSO_4$] to sugarcane (Cv. Co 7318) at sugarcane Research station, Sehore (Madhya Pradesh) in 1989-1990 and 1990-91. They reported that Pushti and Agromin produced 14.2 % and 11.7 % higher yield of sugarcane over the check. The juice quality also improved appreciably.

Srinivas *et al*., (2001) reported that $FeSO_4$ at 0.5 % concentration twice at 45 and 60 DAP along with recommended dose of N,P and K fertilizers has recorded significantly highest number of millable canes, cane yield and CCS yield. Dhanasekaran *et al*., 2004 reported that application of zinc or iron humates improved the cane yield. The interaction effect due to zinc and iron and their source were significant. Application of 5 Kg of zinc and 10 kg of iron ha^{-1} as humates recorded highest cane yield of 157.2 t ha^{-1}which was 41.62 per cent higher than the control. Kadlag *et al*., 2007 reported significant higher cane yield with application of zinc coated suphala @ 2.1 kg ha^{-1} along with N, Pand K fertilizers.

2.13 Effect of micronutrients iron, manganese and zinc on the juice quality parameters of sugarcane

2.13.1 Brix (%,), pol (%), purity coefficient, reducing sugars (%) and CCS (%)

In sugarcane, millable cane number, single cane weight, number of internodes and girth of the cane together contribute for cane yield. However, yield of commercial cane mainly depends on CCS per cent which is largely governed by pol % and cane yield. Mohan Rao *et al.* (1956) observed that spraying Mn produced much better effect than B in improving juice quality. According to Zende (1968), Mn application increased millable cane height and total number of millable canes at harvest resulting in better cane yields. He further reported that dipping of setts in l % $MnSO_4$ solution had a favorable effect on the height of millable canes but had no effect on sucrose per cent juice while effect of spray application of the same on sucrose per cent juice was more distinct. Singh (1972) observed significant improvement in cane yield and juice quality due to foliar application of $FeSO_4$, either singly or in combination with $FeSO_4$ and urea.

Singh *et al.* (1973) concluded from their studies conducted at Shahjahanpur that foliar application of iron as 2% $FeSO_4$ alone or in combination with Mn and nitrogen resulted in significant improvement in juice quality viz., sucrose content (48.2%) and purity coefficient of juice (16.3%) over control. The invert sugars content reduced enormously (-26.9%) owing to which the recovery percent of cane enhanced greatly over control (62.2%). According to Singh and Singh (1973), spray application of iron enhanced cane yield and sucrose per cent juice significantly. Singh *et al*. (1974) conducted experiments on sugarcane at Shahjahanpur (India) from 1952 to 1972 to study the effect of micronutrients (boron, molybdenum, manganese, copper, zinc and iron) on the growth yield and juice quality and reported that the foliar application of Fe, Mn and B generally increased the growth, and quality of juice. Singh *et al*. (1974) observed increase in cane yield to a tune of 10 t /ha due to application of 50 ppm Mn. It was inferred from the studies conducted in Cuddalore tract of Tamil Nadu that application of Mn had beneficial effect on cane yield and juice quality. The pol per cent juice was improved by 0.76 to 0.93 units over control. Zende and Kibe (1977) were of the opinion that application of 5 or 10 ppm Mn either through soil significantly improved the juice quality. Sharma and Rao (1978) were of the opinion that the foliar application of iron had no influence on cane yield although it resulted in significant improvement in CCS per cent in cane. In calcareous soils with low iron availability, soil application of 100 kg $FeSO_4$ ha^{-1} alone or 50 kg $FeSO_4$ + 20 tonnes FYM ha^{-1} or foliar spray of l% $FeSo_4$ solution twice was reported to be beneficial for increased sugar cane yields in Coimbatore district of Tamil Nadu (Anon. 1984).

Gupta and Rao (1980) studied the role of micronutrients (Fe, B, Cu, Zn and Mn) with special reference to Mn on the formation and accumulation of sugar in sugarcane and reported that increasing doses of these micronutrients increased the juice quality and quantity of sugarcane crop. They also discussed the role of Mn as an enzyme activator and its effect on N, sugar, malic acid and mineral metabolism of sugarcane. An increase in Mn application also caused a general increase in leaf chlorophyll content (the effect failing with age of cane) and increase on the contents of fructose, glucose and sucrose. Parthasarathy (1980) conducted experiment on micronutrients in sugarcane and reported that micronutrients like Fe, Cu, and Mo play an important role in the growth and

development of sugarcane plant. He concluded that cane yield can be increased and juice quality could be improved with the application of micronutrients.

Sen *et al*. (1985) found that application of iron singly or in combination with other micronutrients increased the cane yield as well as CCS. Gupta and Rao (1980) studied the role of micronutrients (Fe, B, Cu, Zn and Mn) with special reference to Mn on the formation and accumulation of sugar in sugarcane and reported that increasing doses of these micronutrients increased the juice quality and quantity of sugarcane crop. They also discussed the role of Mn as an enzyme activator and its effect on N, sugar, malic acid and mineral metabolism of sugarcane. An increase in Mn application also caused a general increase in leaf chlorophyll content (the effect failing with age of cane) and increase on the contents of fructose, glucose and sucrose.

Nayyar *et al*. (1984) studied the response of sugarcane to zinc and iron sources and reported that all the yield contributing characters viz. number of tillers, millable canes per stool, cane yield of sugarcane were increased and reported that zinc in combination with N and P increased all the characters i.e. number of tillers per stool, plant height, number of internodes per plant, leaf area, cane brix percentage, pol percentage, CCS percentage, and sugar yield except fibre percentage which showed a negative relationship with the applied elements. Kumaresan *et al*. (1987) reported that pol per cent was improved significantly with application of $ZnSO_4$ (@ 37.5 kg ha^{-1}) and $FeSO_4$ (@100 kg ha^{-1}) over control.

Bangar and Sharma (1992) found that foliar application of $FeSO_4$ significantly increased the sugar yield. Patel *et al*. (1991) conducted field trials in 1987-89 to evaluate the effects of trace elements (Zn, Fe, Mn, and Co) and growth promoters (NAA, ammonium metavanadate and vit.B_1) on yield and quality of sugarcane cv. CoC 671.They concluded that zinc alone or a mixture of trace elements plus growth regulators applied to the soil or foliage under the current fertilizer practices increased the CCS percentage but did not affect cane yield per unit area. Rakkiyappan (1993) stated that 1 % $FeSO_4$ foliar spray and soil application of 150 kg $FeSO_4$ ha^{-1} could be recommended for improving both cane and sugar yields in highly calcareous soil. Spraying of $FeSO_4$ @ 0.5 % at 45 and 60 DAP along with recommended dose of N, P and K fertilizers has recorded

highest sucrose % (21.42 %) when compared to control (19.88 %). Application of both major and micronutrients had further increased the juice % by ferrous sulphtae and zinc sulphate application (Srinivas *et al*., 2001).

Dhanasekaran *et al*. (2004) reported that fertilization with zinc and iron either alone or in combination significantly increased the brix per cent, pol per cent, purity per cent, CCS per cent and sugar yield. The influence was more prominent when these micronutrients were applied as their humates rather than as their salts. They further that application of 5 kg zinc and 10 kg ha^{-1} through humates recorded the highest brix per cent (22.22), pol per cent (19.22), CCS per cent and sugar yield (21.94). Application of N, P and K through uncoated suphala + zinc @ 2.1 kg ha^{-1} numerically recorded higher values of pol per cent (19.95), CCS per cent (11.84) and reducing sugars per cent (1.126) (Kadlag *et al*., 2007).

Occurrence of iron deficiency in calcareous soil leads to chlorosis in sugarcane. Iron deficiency affects the plant growth and development in sugarcane. High HCO_3 in soil rendered iron unavailable to the plant. The efficiency of utilization of micronutrients can be increased by foliar application of micronutrients. Further application of growth regulators has been found to influence the cane yield and improve the juice quality characteristics in sugarcane.

Hence the present study was undertaken to evaluate the physiological role of micronutrients viz., iron, manganese and zinc in combination with Brassinolides and Salicylic acid on the yield and quality of sugarcane variety Co 86032.

CHAPTER III

MATERIALS AND METHODS

The present investigations were carried out in the main season during January to December 2007 in two different locations The first trial was conducted at the Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore and the second trial was conducted in the farmers field at Puttuvikki village, Selvapuram, Coimbatore during the same season with the major objective of studying the physiological aspects of iron nutrition in sugarcane. The details of materials and methodologies adopted in the present study are presented in this chapter.

3.1 Materials

3.1.1 Field Location

The first experiment was conducted in Field No. NA 7, Eastern block of Tamil Nadu Agricultural University, Coimbatore 3 and the second experiment at the farmer's field located at Puttuvikki village, Selvapuram, Coimbatore.

3.1.1.1 Details of the experiment

The field experiments were laid out in Randomized Block Design with twelve treatments and three replications. The details of the treatment are given below:

Treatments : Twelve

T_1 **:** Control

T_2 **:** 1 % $FeSO_4$ spray given at 45,60 and 75DAP

T_3 **:** 1 ppm Brasssinolide spray given at 45,60 and 75DAP

T_4 **:** 150 ppm Salicylic acid spray given at 45,60 and 75DAP

T_5 **:** 1 %$FeSO_4$ +0.5 % $ZnSO_4$ spray given at 45,60 and 75DAP

T_6 **:** 1 %$FeSO_4$ + 0.5 % $MnSO_4$ spray- given at 45,60 and 75DAP

T_7 : 1 %$FeSO_4$ + 0.5 % $ZnSO_4$+ 0.5 % $MnSO_4$ spray given at 45,60 and 75DAP

T_8 : T_3 + T_4

T_9 : T_7 + T_3

T_{10} : T_9 + T_4

T_{11} : Soil application of Micronutrient mixture @ 5 Kg

T_{12} : Soil application of Micronutrient mixture @ 5 Kg + 1 ppm Brasssinolide + 150 ppm Salicylic acid spray given at 45,60 and 75DAP

Common treatment : 100 ppm Citric Acid + 1 %Urea

Plot size	:	6 m x 5 m
Spacing between rows	:	90 cm
Date of sowing	:	03.01.2007 -(Trial I) 12.01.2007-(Trial II)
Date of harvesting	:	05.12..2007-(Trial I) 18.12.2007- (Trial II)

3.1.1.2 Soil characteristics and Water quality

The physical and chemical characteristics of the soils and the quality of irrigation water used for the two experimental trials (Trial I & II) are detailed below

Table 1. Physico – Chemical properties of the soil of experimental field. Trial – I (Field No. NA 7)

Characters	
Mechanical analysis (Piper, 1950)	
Clay (%)	27.90

Silt (%)	16.10
Fine sand (%)	18.30
Course sand (%)	33.70
Bulk density	1.40
Chemical analysis	
Organic carbon	0.42
Available N (kg ha^{-1}) (Subbaiah and Asija, 1956)	215.00
Available P (kg ha^{-1}) (Olsen *et al.,* 1954)	11.30
Available K (kg ha^{-1}) (Stanford and English, 1949)	290.00
pH (1:2 soil water extract)	7.90
EC (dsm^2) (1:2 Soil water extract)	0.40

Table 2. Quality of water used for irrigation

Characters	**Bore well water** (Eastern Block farm)
1. E C (dS m^{-1})	4.6
2. pH	7.6
3. Anions (meq^{-1})	
a. Carbonates	Trace
b. Bicarbonates	8.0
c. Chlorides	26.0
d. Sulphates	15.7

4.	Cations ((meq^{-1})		
	e.	Calcium	12.7
	f.	Magnesium	12.3
	g.	Sodium	15.7
	h.	Potassium (ppm)	14.0
5.	Soluble sodium percentage (SSP)		19.2
6.	Sodium adsorption ratio (SSR)		1.15
7.	Water table		35 m below

Table 3. Physico – Chemical properties of the soil of experimental field. Trial – II (Farmers field)

Characters	
Mechanical analysis (Piper, 1950)	
Clay (%)	28.60
Silt (%)	17.30
Fine sand (%)	19.80
Course sand (%)	35.10
Bulk density	1.52
Chemical analysis	
Organic carbon	0.49

Available N (kg ha-1) (Subbaiah and Asija, 1956)	221.00
Available P (kg ha-1) (Olsen et al., 1954)	13.80
Available K (kg ha-1) (Standford and English, 1949)	296.00
pH (1:2 soil water extract)	6.40
EC (dsm^2) (1:2 Soil water extract)	0.37

Table 4. Quality of water used for irrigation

Characters		**Bore well water**
1.	E C (dS m^{-1})	4.1
2.	pH	6.2
3.	Anions (meq^{-1})	
	a. Carbonates	Trace
	b. Bicarbonates	6.8
	c. Chlorides	20.0
	d. Sulphates	13.2
4.	Cations ((meq^{-1})	
	e. Calcium	10.5
	f. Magnesium	14.9
	g. Sodium	12.2
	h. Potassium (ppm)	16.1
5.	Soluble sodium percentage (SSP)	15.4

6.	Sodium adsorption ratio (SSR)	1.03
7.	Water table	30 m below

3.1.2 Weather parameters

The weather conditions prevailed during the entire cropping period and the meteorological data collected from the Meteorological observatory of Tamil Nadu Agricultural University, Coimbatore are presented in table 5.

3.1.3 Preparation of field

The field was first ploughed with a disc plough followed by passing of a cultivar twice and then leveled. The field was opened up into ridges and furrows at distance of 90 cm apart uniformly. Plots were marked as per the specified size. Irrigation and drainage channels were provided according to the need.

3.1.4 Seed material

The sugarcane variety Co 86032 was used as the test crop. This is better than CoC 671 with respect to yield and quality.

3.1.5 Planting

Healthy two budded setts were planted at the rate of 80,000 setts ha^{-1} *i.e.*, 36 setts per 6 metre row and 216 setts in each plot on 03.01.2007 in trial I and on 12.01.2007 in trial II. Sett treatment was done by dipping them in a solution containing 125 g of bavistin and 2.5 kg of urea in 250 litres of water for fifteen minutes to avoid fungal infection. After irrigating the plots, the setts were planted horizontally in the furrows continuously.

3.1.6 Fertilizer application

Nitrogen as urea, phosphorus as single super phosphate and potassium as muriate of potash were applied @ 275.0:62.5:112.5 kg ha^{-1}.

The entire quantity of phosphorus was applied as the basal dose, while nitrogen and potassium were applied in three equal splits on 30^{th}, 60^{th} and 90^{th} day after planting. The treatments T_1 to T_{10} and T_{12} were given as foliar sprays on 45, 60 and 75 days after planting while T_{11} was given as soil application as per the treatment schedule.

3.1.7 Herbicide spraying

Atrazine was sprayed @ 2.5 kg ha^{-1} on third day after planting uniformly to all the plots.

3.1.8 Irrigation

The first irrigation was given immediately after planting followed by life irrigation on the third day. Thereafter, irrigation was given once in 6 days up to 120 days, once in 7 days from 120 days to 270 days and once in 10 days from 270 days till harvest.

3.1.9 Intercultural operations

Earthing up was done at all three times of top dressing (first two half earthing up and finally full earthing up). Hand weeding was done twice on 25^{th} and 45^{th} day after planting. Detrashing was done on 120^{th} and 180^{th} day after planting.

3.1.10 Harvest

Trial I was harvested at the completion of 11^{th} month after planting i.e., on 05.12.2007 and the Trial II was harvested on 18.12.2007. The yield of cane were recorded in each plot and expressed in t ha^{-1}.

3.2 Methods

3.2.1 Observations recorded

The following biometric, physiological / biochemical, cane yield and juice quality characteristics were recorded from the net plot area in trial I and in trial II.

3.2.1.1 Biometric observations

3.2.1.1.1Germination per cent

Germination count was recorded on 40th day after planting from the net plot area and expressed as percentage of germinated bud to the total number of buds planted.

3.2.1.1.2 Tiller number

Tiller count was taken on 100th day after planting from the net plot area and expressed as number of tillers per germinated bud (inclusive of mother shoot) or tillering capacity (per row basis).

3.2.1.1.3 Economic shoot population

The economic shoot population was recorded at 120th day after planting and expressed as number per hectare.

3.2.1. 2 Growth analysis

3.2.1.2.1 Leaf area

Leaf area was measured by leaf area meter (Model L1-3100 of Inc., Lincoln, and Nebrask, USA) and expressed as cm^2 per plant.

3.2.1.2.2 Leaf area index (LAI)

The leaf area index was calculated by employing the formula of Williams (1946)

$$LAI = \frac{\text{Leaf area per plant}}{\text{Ground area occupied per plant}}$$

3.2.1.2.3 Net assimilation rate (NAR)

The method proposed by Williams (1946) was employed for measuring NAR on leaf area basis and the values were expressed in mg cm^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e L_2 - Log_e L_1}{L_2 - L_1}$$

W_1 and W_2 - Dry weight of whole plant at t_1 and t_2, respectively

L_1 and L_2 - Leaf area at t_1 and t_2, respectively

$t_2 - t_1$ - Time interval in days

3.2.1.2.4 Relative growth rate (RGR)

The relative growth rate was calculated by using the formula suggested by Williams (1946) and expressed in mg g^{-1} day^{-1}.

$$RGR = \frac{Log_e W_2 - Log_e W_1}{(t_2 - t_1)}$$

W_1 and W_2 - Whole plant dry weight at t_1 and t_2 respectively

$t_2 - t_1$ - Time interval in days

3.2.1.2.5 Crop growth rate (CGR)

The crop growth was estimated by using the formula of Watson (1956) and expressed in g m^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

W_1 and W_2 - Whole plant dry weights at time t_1 and t_2 respectively

$(t_2 - t_1)$ - Time in days

P - Ground area occupied by the plant (m^2)

3.2.1.2.6 Leaf area duration (LAD)

Leaf area duration was determined by using the formula of Kvet *et al.* (1971) and the values were expressed in days.

$$LAD = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

L_1 - LAI at first stage

L_2 - LAI at second stage

$(t_2 - t_1)$ - Time interval in days between stages

3.2.1.2.7 Specific leaf area (SLA)

Specific leaf area was calculated by employing the following formula of Kvet *et al* (1971) and expressed in cm^{-2} g^{-1}.

$$SLA = \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

3.2.1.2.8 Specific leaf weight (SLW)

Specific leaf weight was calculated by employing the following formula of Pearce *et al.* (1968) and expressed in mg cm^{-2}.

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

3.2.1.3 Physiological and biochemical parameters

Physiological and biochemical investigations were carried out in all treatments utilizing the first fully opened leaves (+1 TVD).Triplicate samples were taken for analysis and data analyzed statistically.

3.2.1.3.1 Net photosynthetic rate

Net photosynthetic was measured using photosynthesis system CI -320 PS (CI- 301 CO_2 Gas Analyser) of CID, Inc. Vancouver, Washington State, USA and expressed in units of μ mol m^{-2} s^{-1}.

3.2.1.3.2 Transpiration rate

Transpiration rate was measured using photosynthesis system CI -320 PS (CI- 301 CO_2 Gas Analyser) of CID, Inc.Vancouver, Washington State, U.S.A and expressed in units of m mol m^{-2} s^{-1}.

3.2.1.3.3 Stomatal conductance

Stomatal conductance was measured using photosynthesis system CI -320 PS (CI-301 CO_2 Gas Analyser) of CID, Inc.Vancouver, Washington State, U.S.A and expressed in units of m mol m^{-2} s^{-1}.

3.2.1.3.4 Chlorophyll meter readings (SPAD index)

Chlorophyll meter from Minolta (model 502 of Minolta, Japan) was used to measure SPAD index. Measurements were taken from top most fully expanded leaf. Five readings were taken from each replication and the average values were computed using the method described by Minolta (1989) and Lu and Zhang (1989).

3.2.1.3.5 PS II efficiency (Fv/Fm)

Chlorophyll fluorescence measurements were made with Plant Efficiency Analyzer (PEA), (Hansatech, UK).

3.2.1.3.6 Chlorophyll content

Chlorophyll content in leaves was estimated using the method described by Yoshida *et al*. (1971) and expressed as mg g^{-1} fresh weight. The chlorophyll content was calculated using the formula described below

$$\text{Chlorophyll a} = \frac{(12.7 \times \text{O.D. at } 663) - (2.54 \times \text{O.D. at } 645)}{W} \times V$$

$$\text{Chlorophyll b} = \frac{(22.9 \times \text{O.D. at } 645) - (4.68 \times \text{O.D. at } 663)}{W} \times V$$

$$\text{Total chlorophyll} = \frac{\text{O.D. at } 652}{34.5 \times W} \times V$$

Where,

W – Weight of the leaf sample (g)

V – Volume of supernatant solution made-up (ml)

O.D – Optical Density

3.2.1.3.7 Soluble protein

Soluble protein content of leaves was estimated by using the method of Lowry *et al*. (1951) and expressed as mg g^{-1} fresh weight.

3.2.1.3.8 Cation exchange capacity of roots

The method of Crook (1964) was followed to determine the CEC of the roots and expressed in meq 100 $g^{-1}$of roots.

3.2.1.3.9 Catalase activity

Catalase activity was determined by titrimetric method using $KMnO_4$ (Gopalachari, 1963) and expressed as μg H_2O_2 g^{-1} min^{-1}.

3.2.1.3.10 Peroxidase activity

Peroxidase activity (Δ430 nm g^{-1} min^{-1}) was determined according to Perur (1962).

3.2.1.4 Nutritional Status

3.2.1.4.1 Soil

The micronutrients viz., iron and manganese were extracted with DTPA extractant in the ratio of 1:2 (0.005 M DTPA – Diethylene triaminepenta acetic acid, ie. 1.965 g + 0.1 META – Trietanolamine buffer i.e., 14.9 ml + 0.1 M $CaCl_2$, 2 H_2O ie., 1.47 g dissolved in 1 litre of water). It was adjusted to pH 7.3 with dil. HCl, shaken for 2 hours and filtered through Whatman No.42 filter paper and estimated with AAS and expressed in parts per million (ppm) in the soil samples at 150, 210 and 270 days after planting.

3.2.1.4.2 Root

The plant samples were collected for recording the dry matter production at 55, 70, 90, 150, 210 and 270 DAP. The root samples were washed with 0.1 N redistilled HCl

followed by double distilled water to remove external contamination. The root samples were dried at 60 ^{0} C till constant weight. The root samples were powdered in a stainless steel grinder and used for analysis. The analysis of nutrients was done in root samples as per the procedure outlined below.

Method of analysis

No.	Estimation	Author	Remarks
a.	Triple acid extract	Piper (1966)	Conc. Nitric acid, Sulphuric acid and Perchloric acid in the ratio of 9:2:1.
b.	Phosphorus	Jackson (1973)	Vanado-molybdate method
c.	Micronutrients	Jackson (1973)	Triple acid extract fed in to AAS

Wet digestion of 1 g plant material (root) was carried out with 12 ml triple acid extract (Nitric acid, Sulphuric acid and Perchloric acid in the ratio of 9:2:1 respectively). The digested sample was made upto a desired volume (Jackson, 1967). The total iron, manganese and zinc in the triple acid extract were estimated using AAS and expressed in ppm in the roots at various stages of sampling.

3.2.1.4.3 Metabolically active iron

Metabolically active iron was estimated in the roots by using the method of Katyal and Sharma (1980) and expressed in ppm on fresh weight basis.

3.3 Yield parameters

3.3.1 Number of millable canes

The number of millable canes was counted in each plot at harvest.

3.3.2 Cane weight

Six canes at random from each plot were cut at the bottom, detopped at mature internode level and the cane weight was measured and average cane weight was calculated.

3.3.3 Height, girth and internodes per millable cane

Six canes were selected at random from each plot and cut at the bottom, detopped at mature internode level and the cane length /height and number of internodes per millable cane were recorded at harvest from randomly selected six canes from the net plot area and data expressed as mean of the canes. The cane girth of the randomly selected cane samples was measured by using Vernier caliper at bottom, middle and top portion of the cane at harvest and the mean values expressed in cm.

3.3.4 Internodal length

Average internodal length was computed from the number of internodes and cane length and expressed in cm.

3.3.5 Single cane weight

Single cane weight was computed form the number of canes presents in two rows selected at random and expressed as g pl^{-1}.

3.3.6 Cane yield

Weight of cane harvested from each net plot area was recorded and expressed as tonnes $ha^{-1.}$

3.4 Cane juice quality characteristics

Six canes were cut at random from each plot and juice was extracted in a small crusher. The juice was filtered through a muslin cloth to remove sediments and dust materials .Juice samples were drawn from composite juice of all the six canes and were analyzed for various quality parameters.

3.4.1 Brix (%), Pol (%) and Purity coefficient (%)

Juice quality parameters such as brix, pol and purity were determined from six randomly selected canes at harvest. The juice brix, sucrose per cent and purity were analysed in an automatic 'sucrolyser system' developed by Electronic-Automation of West Germany. Before feeding into the instrument, juice was clarified by using Horne's dry lead sub-acetate (Meade and Chen, 1977). Purity co-efficient was worked out as percentage of sucrose to total solids.

3.4.2 Reducing sugars

The content of reducing sugars in juice was estimated calorimetrically by alkaline potassium ferricyanide method (Chiranjivi Rao and Asokan, 1974) and expressed as per cent.

3.4.3 Commercial cane sugar

Commercial cane sugar (CCS) per cent was calculated as follows (Meade and Chen, 1977) and expressed as per cent.

$$\text{CCS \%} = 1.022 \text{ pol in juice \%} - 0.292 \text{ brix \% in juice}$$

3.4.4 Sugar yield (t ha^{-1})

Sugar yield per hectare was calculated from the commercial cane sugar per cent and cane sugar per cent and cane yield by using the formula (Meade and Chen, 1977) and expressed as t ha^{-1}

$$\text{CCS (t ha}^{-1}) = \frac{\text{CCS \% x Yield of cane (t ha}^{-1})}{100}$$

3.5 Benefit: Cost ratio

Benefit: Cost ratio was calculated for each treatment based on the prevailing cost of cultivation charges and cost of nutrients and plant growth regulator.

3.6 Statistical analysis

The data on various observations recorded during the course of the investigation were analyzed statistically by adopting the procedure described by Gomez and Gomez (1984).

CHAPTER IV

EXPERIMENTAL RESULTS

Field experiments were carried out to evaluate the impact of foliar application of micronutrients and plant growth regulators on morphological, physiological, biochemical, yield components and quality of sugarcane. The experiments were conducted at two locations. The first trial was conducted at the Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore during the main season (January planting) of 2007-2008 and the second trial was conducted in the farmers field at Puttuvikki village, Selvapuram, Coimbatore during the main season ((January planting) of 2007-2008.The micronutrients viz., iron, manganese, zinc and plant growth regulators like brassinolide and salicylic acid were sprayed through foliage individually and in combination. Biometric, physiological / biochemical characteristics were recorded at different time intervals (55, 70, 90,150,210 and 270 DAP) on the sugarcane (cv. Co 86032). The yield and juice quality characteristics were recorded at harvest. The results of the experiment are presented in this chapter.

4.1 Biometric attributes

4.1.1 Germination (40 DAP) (%)

The germination percentage was worked out by counting the number of germinated shoots divided by the total number of buds planted. The results of the trial I revealed that there was no significant variation in the germination percentage as observed at 40 DAP, since the treatments were imposed only from 45 days after planting.(Table 6).

The results of the trial II also followed the similar trend as that of trial I with respect to germination percentage observed at 40 days after planting (Table 7).

4.1.2 Tillering capacity (100 DAP) (lakh ha^{-1}).

The effect of various treatments on the tillering capacity of trial I is presented in table 6. Significantly higher mean tillering was observed in T_9 (1.67) which was closely

followed by T_8 (1.54) and T_{12} (1.50). Lower tillering capacity of 1.19 was recorded in $T_{10.}$

The trial II also followed a similar trend as observed for trial I with higher tillering in T_9 (1.69) which was closely followed by T_8 (1.56) and T_{12} (1.52) (Table 7). Here also, T_{10} recorded the lower tillering capacity of 1.21 lakhs ha^{-1}.

4.1.3 Shoot population (120 DAP) (lakh ha^{-1}).

With respect to the shoot population (120 DAP), there was significant variation among the treatments in trial I. Higher shoot population was observed in T_9 (1.88) followed by T_{12} (1.86) and T_7 (1.84). Control (T_1) recorded the lowest shoot population of 1.61 lakhs ha^{-1} (Table 6).

Significant variation was seen in trial II with respect to the shoot population. The shoot population followed similar trend as that of trial I with higher shoot population in T_9 (1.90), T_{12} (1.89) and T_2 (1.87) while Control (T_1) recorded lower shoot population of 1.64 lakhs $ha^{-1.}$ (Table 7).

4.1.4 Single cane dry weight (g $plant^{-1}$)

Time trend of dry weight of single cane of trial I as influenced by chosen treatments and intervals of observation are presented in table 8. The mean values of single cane dry weights showed an increasing trend from 55 to 270 days after of planting (DAP). The mean values of different interval of time were found to be 81.88, 141.17, 193.64, 593.06, 959.40 and 1165.00 g $plant^{-1}$ at 55, 70, 90,150,210 and 270 DAP respectively. The mean performance of the treatments indicated that the dry weight of single cane was higher with T_9 (604.51g pl^{-1}) followed by T_{12} (569.04), T_7 (552.44).Lowest cane dry weight was observed in T_1 (481.98).Treatment T_9 maintained its supremacy in single cane dry weight during all the intervals of time. However significant increased cane dry of 1410 g pl^{-1} was observed in T_9 at 270 DAP.

Effect of various treatments on dry weight of single cane of trial II is presented in table 9. The mean values of single cane dry weights showed an increasing trend from 55 to 270 days after of planting as in trial I. The mean values of different intervals of time

were found to be 89.93, 152.21, 208.66, 607.20, 999.96 and 1254.58g pl^{-1} at 55, 70, 90,150,210 and 270 DAP respectively .The dry weight of cane attained a statistical significance in various treatments and stage studied. The mean performance of the treatments indicated a similar trend as that of trial II with higher mean cane dry weight recorded in T_9 (598.52) and lower in T_1 (497.13g pl^{-1}). Treatment T_9 maintained its superiority in single cane dry weight at all stages of growth with highest single cane dry weight of 1370 g pl^{-1} at 270 DAP.

4.2 Growth analysis

4.2.1 Leaf Area index (LAI)

Influence of various treatments and intervals of observation on leaf area index (LAI) of trial I was presented in table 10. The mean values of leaf area index were found increase from 55 to 270 DAP. The mean values for different intervals of time were found to be 1.78, 2.11, 2.43, 3.32, 4.19 and 5.12 at 55, 70, 90,150,210 and 270 DAP respectively. Mean performance of the treatments indicated that the LAI was higher with T_9 (3.67) which was significantly superior to the rest of the treatments. However the lowest value was observed in T_4 (2.97). At 270 DAP, T_9, had significantly increased LAI values (5.97) which was on par with T_{12} (5.62), T_7 (5.26) and T_3 (5.30) during the same stage whereas in control (T_1) the LAI was only 4.71.

The LAI of trial II as influenced by various treatments and intervals of observation are presented in table 11. The mean values of LAI showed an increasing trend from 55 to 270 DAP as in trial I. The mean values for different intervals of time were found to be 1.90, 2.26, 2.59, 3.55, 4.46 and 5.42 at 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments followed a similar trend as that of trial I with higher LAI values in T_9 (3.88) and lower in T_4 (3.16). Among the treatments, T_9 maintained its supremacy in LAI during all the sampling time which was followed by T_{12} (3.68) and T_7 (3.50). Maximum LAI was recorded in T_9 at 270 DAP (6.32) and this was followed by T_{12} (5.98) whereas a LAI of only 3.12 was recorded in control (T_1) during the same stage.

4.2.2 Crop growth rate (g m^{-2} day^{-1})

Time trend of crop growth rate (CGR) of trial I as influenced by chosen treatments and intervals of time are presented in table 12.The mean values of CGR increased from 55-70 to 210-270 DAP. The mean values of CGR for different intervals of time were found to be 5.94, 7.66, 10.14, 12.75 and 14.23 g m^{-2} day^{-1} at 55, 70, 90, 150,210 and 270 DAP respectively. The mean performance of the treatments indicated that the CGR was higher with T_9 (14.08) followed by T_{12} (11.66), T_7 (10.68). At 210-270 DAP, T_9 recorded higher CGR of (20.40) followed by T_7 (18.20) and T_{12} (16.60). Treatment T_9 maintained its supremacy in CGR during all the intervals of time. Lowest mean CGR of 7.72 g m^{-2} $day^{-1}$was recorded control (T_1).

Time trend of crop growth rate (CGR) of trial II as influenced by chosen treatments and intervals of time are presented in table 13. As in trial I, CGR increased from 55-70 to 210-270 DAP. The mean values of CGR for different intervals of time were found to be 6.47, 8.31, 11.05, 14.28 and 15.32 g m^{-2} day^{-1} at 55 DAP, 70 DAP, 90 DAP, 150 DAP, 210 DAP and 270 DAP respectively. The mean performance of the treatments indicated a similar trend as that of trial I with higher CGR in T_9 (14.90), followed by T_{12} (13.33) and T_7 (12.40).Treatment T_9 maintained its supremacy in RGR during all the intervals of observation. As in trial I the lower mean CGR of 8.00 g m^{-2} day^{-1} was recorded in control (T_1).

4.2.3 Relative growth rate (mg g^{-1} day^{-1})

The influence of various treatments and intervals of observation on relative growth rate (RGR) of trial I is presented in table 14. The mean value of RGR was found to decline progressively from 55-70 to 210-270 DAP. The mean values of RGR for different intervals of time were found to be 36.30, 15.81, 18.65, 7.99 and 3.35 mg g^{-1} day $^{-1}$ at 55, 70, 90,150,210 and 270 DAP respectively. The mean performance of the treatments indicated that the RGR was higher in T_9 (17.36) and closely followed by T_{12} (17.23) and T_2 (16.42). At 150-210 DAP, T_9 possessed higher RGR values of 8.93 mg g^{-1} day^{-1} which was comparable with T_{12} (8.63), T_6 (8.63) and T_2 (8.31). Among the treatments T_9 maintained its supremacy in RGR during all the intervals of time. Lower mean RGR of 15.85 mg g^{-1} $day^{-1}$was recorded in control (T_1).

The RGR as influenced by chosen treatments and intervals of time for trial II are presented in table 15. The RGR declined from 55-70 to 210-270 DAP. The mean values of RGR for different intervals of time were found to be 37.21, 16.26, 18.96, 8.28 and 3.50 at 55, 70, 90, 150,210 and 270 respectively. The mean performance of the treatments followed a similar trend as that of trial I with higher RGR in T_9 (17.87) followed by T_{12} (17.14), T_7 (17.07). Control (T_1) recorded lower RGR of 16.45 mg g^{-1} day^{-1}.

4.2.4 Net assimilation rate (mg cm^{-2} day^{-1})

The net assimilation rate (NAR) as influenced by the chosen treatments and intervals of observation for trial I is presented in table 16.The mean values of NAR increased from 55-70 to 150-210 DAP and thereafter a gradual decline was observed at 210-270 days after planting. The mean values for different intervals of time were found to be 29.92, 33.22, 35.65, 35.77 and 30.32 mg cm^{-2} day^{-1}at 55, 70, 90, 150, 210 and 270 DAP respectively. Mean performance of the treatments indicated that NAR was higher with T_9 (38.40) followed by T_{12} (36.70) and T_7 (35.90); lower values of NAR were observed in control ($T_{1)}$ (25.49). At 150-210 DAP, treatment T_9 recorded higher NAR of 42.15 mg cm^{-2} day^{-1} which was on par with T_{12} (40.78) and T_7 (39.25).Similar trend was evident with rest of date of sampling.

The effect of various treatments and intervals of observation on the NAR of trial II is presented in table 17. The mean values of NAR increased from 55-70 to 150-210 DAP and thereafter gradually declined at 210-270 DAP. The mean values for different intervals of time were found to be 30.07, 33.39, 35.82, 36.01and 30.50 mg cm^{-2} day^{-1}at 55, 70, 90,150,210 and 270 DAP respectively. The mean performance of the treatments followed a similar trend as that of trial I with higher NAR in T_9 (38.57) whereas in control (T_1) the NAR was only 25.63 mg cm^{-2} day^{-1}.

4.2.5 Leaf area duration (days)

Leaf area duration (LAD) as influenced by different treatments and intervals of time of trial I is presented in table 18.The LAD increased from 55-70 to 210-DAP. The mean values of LAD for different phases were found to be 29.20, 45.47, 172.60, 226.40

and 281.87 days at 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments was higher with T_9 (183.84) followed by T_3 (182.64) and T_{12} (161.06). Treatment T_9 maintained its supremacy in LAD during all the intervals of time. At 210-270 DAP T_9 recorded higher LAD of (363.20 days) while control (T_1) recorded the lower mean LAD of 139.54 days.

The influence of various treatments and intervals of time on LAD of trial II is shown in table19. The LAD increased from 55-70 to 210-270 DAP. The mean values of LAD for different intervals of time were found to be 29.93, 46.58, 176.21, 232.94 and 287.59 days during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments indicated a similar trend as that of trial I with higher LAD in T_9 (188.72) followed by T_{12} (165.84), T_7 (160.80). As observed in trial I treatment, T_9 maintained its supremacy in LAD during all the intervals of time. At 210-270 DAP treatment T_9 recorded higher LAD (374.6) while control (T_1) recorded the lowest LAD (143.76).

4.2.6 Specific leaf area ($cm^2 g^{-1}$)

Time trend of specific leaf area (SLA) of trial I as influenced by chosen treatments and intervals of time are shown in table 20.The SLA increased from 55 to 270 DAP. Mean values of SLA for different intervals of time were found to be 134.36, 139.27, 144.23, 147.93, 152.27 and 156.61 $cm^2 mg^{-1}$ at 55, 70, 90, 150 , 210 and 270 DAP respectively .The mean performance of the treatments indicated higher SLA in T_9 (159.04) followed by T_{12} (154.73), T_{10} (153.33). At 270 DAP, T_9 recorded higher SLA of 172.8 $cm^2 mg^{-1}$ which was on par with T_{12} (169.7) and T_{10} (166.2). Treatment T_9 maintained its supremacy in SLA during all the intervals of time while control (T_1) recorded lower SLA of 137.02 $cm^2 mg^{-1}$.

The effect of various treatments and sampling dates on the SLA of trial II is presented in table 21.The SLA increased from 55 to 270 DAP. The mean values of SLA for different intervals of time were found to be 135.70, 140.66, 145.50, 150.00, 153.83 and 158.16 $cm^2 mg^{-1}$ at 55, 70, 90, 150, 210 and 270 DAP respectively. Mean performance of the treatments indicated a similar trend as that of trial I with higher SLA in T_9 (160.62) followed by T_{12} (156.27) and T_7 (154.80).At 270 DAP T_9 recorded higher

SLA of 174.5 $cm^2 g^{-1}$ which was on par with T_{12} (171.4) and T_7 (167.90). As in trial I, T_9 maintained its supremacy in SLA during all the intervals of observation. Control (T_1) recorded lower mean SLA of 138.38 $cm^2 g^{-1}$.

4.2.7 Specific leaf weight (mg cm^{-2})

The influence of various treatments and stages on specific leaf weight (SLW) of trial I is shown in table 22.The SLW showed a declining trend from 55 to 270DAP. The mean values of SLA for different intervals of time were found to be 8.60, 8.08, 7.78, 7.32, 7.10 and 6.93 mg cm^{-2} during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments indicated a higher SLW in T_9 (8.12) followed by T_1 (8.04), T_{12} (7.92).At 270 DAP, T_9 recorded higher SLW of 7.49 mg cm^{-2}. Treatment T_9 maintained its supremacy in SLA during all the intervals of observation. Lower SLW of 7.18 mg cm^{-2} was observed in treatment T_4.

The effect of various treatments and intervals of time on the SLW for trial II is presented in table 23.The SLW showed a declining trend from 55 to 270 DAP as observed in trial I. The mean values of SLA for different intervals of time were found to be 8.94, 8.47, 8.13, 7.68, 7.46 and 7.25 mg cm^{-2} during 55, 70, 90, 150, 210 and 270 DAP. The mean performance of the treatments indicated a similar trend as that of trial I with higher SLW in T_9 (8.52) followed by T_{12} (8.44) and T_7 (8.32). As observed in trial I, T_4 recorded lower SLW of 7.53 mg cm^{-2}.

4.3 Physiological and biochemical parameters

4.3.1 Chlorophyll 'a' (mg g^{-1}).

Time trend of chlorophyll ‘a’ content in field trial I as influenced by the chosen treatments and stages was presented in table 24.The chlorophyll content increased from 55 to 210 DAP with a declining trend thereafter at 270 DAP. The mean values of chlorophyll ‘a’ for different intervals of time were 0.710, 0.934, 1.054, 1.400, 1.711 and 1.517 mg g^{-1} during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments indicated that the chlorophyll ‘a’ content was higher with T_9, (1.291) followed by T_6 (1.280), T_2 (1.275) with the lower value observed with T_{12}

(1.076). However, significantly increased content of 1.845 mg g^{-1} of chlorophyll ‘a’ was observed with T_{12} at 210 DAP.

Time trend of chlorophyll 'a' content in field trial II as influenced by the chosen treatments and stages was presented in table 25. The chlorophyll ‘a’ content increased from 55 to 210 DAP with a declining trend thereafter at 270 DAP as observed in field trial I. The mean values of chlorophyll ‘a’ for different intervals of time were found to be 0.749, 1.098, 1.321, 1.505, 1.779 and 1.551 mg g^{-1} during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments indicated that the chlorophyll 'a' content was higher with T_9 (1.407) followed by T_{12} (1.390) and T_6 (1.385). Lower mean chlorophyll ‘a’ content was observed with T_1 (1.241). However, significantly increased content of 1.862 mg g^{-1} was observed with T_{12} at 210 DAP.

4.3.2 Chlorophyll 'b' (mg g^{-1}).

The content of chlorophyll 'b' in trial I as influenced by the chosen treatments and in different stages was presented in the table 26 . The values were found to increase from 55 to 210 DAP with a declining tread thereafter at 270 DAP. The mean values of chlorophyll ‘b’ for different intervals of time were found to be 0.280, 0.391, 0.467, 0.519, 0.616 and 0.548 mg g^{-1} during 55,70, 90, 150, 210 and 270 DAP. The mean performance of the treatments indicated that the chlorophyll ‘b’ content was higher with T_6 (0.499) and closely followed by T_9 (0.491) and T_4 (0.489). However, increased content of 0.680 mg g^{-1} was evident with T_4 at 210 DAP. Nevertheless this was found to be on par with T_6 (0.661), T_2 (0.648) and T_8 (0.615). Lower mean chlorophyll ‘b’ content of 0.454 mg g^{-1} was recorded in control (T_1).

The content of chlorophyll 'b' in field trial II as influenced by the chosen treatments and stages was given in table 27. The chlorophyll 'b' content was found to increase from 55 to 210 DAP with a declining trend thereafter at 270 DAP. The mean values of chlorophyll ‘b’ for different intervals of time were found to be 0.282, 0.410, 0.477, 0.549, 0.647 and 0.568 mg g^{-1} during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments indicated a different trend with

higher values in T_9 (0.509) and closely followed by T_{12} (0.502. However, increased chlorophyll 'b' content of 0.677 mg g^{-1} was evident with T_9 at 210 DAP. Nevertheless this was found to be on par with T_4 (0.664), and T_3 (0.654). Lower mean chlorophyll 'b' content of 0.441 mg g^{-1} was observed in control (T_1).

4.3.3 Total chlorophyll (mg g^{-1})

Total chlorophyll content of trial I as influenced by the chosen treatments and intervals of time was presented in table 28. The total chlorophyll content showed a linear increase from 55 to 210 DAP with a declining trend thereafter at 270 DAP. The mean values of total chlorophyll for different intervals of time were found to be 0.989, 1.400, 1.653, 1.836, 2.327 and 2.065 mg g^{-1} during 55,70, 90, 150, 210 and 270 DAP respectively. The mean value of the treatments indicated the total chlorophyll content was higher with T_9 (1.819) followed by T_{12} (1.782) and T_6 (1.748). At 210 DAP, T_4 registered high total chlorophyll content of 2.474 mg g^{-1} which was comparable with T_4 (2.455) T_2 (2.450) and T_9 (2.425). Lower total chlorophyll content was observed in T_2 (1.544) at the same stage.

Total chlorophyll content of Trial II as influenced by the chosen treatments and stages was presented in table 29.The total chlorophyll content showed a linear increase from 55 to 210 DAP and thereafter a decline at 270 days DAP as observed in trial I. The mean values of total chlorophyll were found to be 1.031, 1.513, 1.800, 2.039, 2.372 and 2.113 mg g^{-1} during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean value of the treatments indicated the total chlorophyll content was higher with T_9 (1.917) followed by T_{12} (1.892) and T_3 (1.875). At 210 DAP, T_9 registered high total chlorophyll content of 2.547 mg g^{-1} which was comparable with T_3 (2.524) T_5 (2.519) and T_{12} (2.509). Lower total chlorophyll content of 1.683 mg g^{-1} was observed in control (T_1) during the same stage.

4.3.4 Chlorophyll a/b ratio

The influence of various treatments and intervals of observation on the chlorophyll a/b ratio of trial I is presented in Table 30.The chlorophyll a/b ratio increased from 55 DAP to 210 DAP and thereafter a decline at 270 DAP was observed. The mean

values of chlorophyll a/b ratio for different intervals of time were found to be 2.54, 2.58, 2.68, 2.76, 2.78 and 2.77 during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments indicated that the Chlorophyll a/b ratio was higher with T_9 (2.86) followed by T_3 (2.75), T_4 (2.74) and T_{10} (2.73). The treatment T_9 possessed higher chlorophyll a/b ratio at 70 DAP (2.75), 150 DAP (2.95), 210 DAP (3.05) and 270 DAP (2.92). Lower chlorophyll a/b ratio was observed in T_4 (2.56).

Time trend of chlorophyll a/b ratio of Trial II as influenced by the chosen treatments and intervals of time was given in Table 31. As observed in trial I, the ratio increased from 55 DAP to 270 DAP. The mean values of chlorophyll a/b ratio for different intervals of time were found to be 2.65, 2.69, 2.77, 2.84, 2.88 and 2.89 during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments indicated that the chlorophyll a/b ratio was higher with T_9 (2.96) followed by T_3 and T_7 (2.83), T_{10} (2.82) and T_2 (2.80). At 210 DAP, treatment T_9 recorded higher chlorophyll a/b ratio of 3.15 while the lower chlorophyll a/b ratio was observed in T_{11} (2.65).

4.3.5 Chlorophyll fluorescence (Fv/Fm)

Time trend of chlorophyll fluorescence as influenced by various treatments and intervals of time of the Trial I was presented in table 32.The chlorophyll fluorescence values were found to increase form 55 DAP to 210 DAP and thereafter a decline was observed at 270 DAP. The mean values of chlorophyll fluorescence for different intervals of time were found to be 0.729, 0.769, 0.820, 0.847, 0.873 and 0.825 during 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of the treatments indicated that the chlorophyll fluorescence was higher with T_9 (0.879) followed by T_{12} (0.845), and T_7 (0.842). At 210 DAP, T_9 had significantly increased chlorophyll fluorescence values of 0.940 which was on par with T_{12} (0.927), T_7 (0.910) during the same stage. Lower chlorophyll fluorescence values were observed in T_{11} and T_4 (0.767).

The influence of various treatments and stages on the chlorophyll fluorescence of Trial II was presented in Table 33. The chlorophyll fluorescence values increased from 55 DAP to 210DAP and thereafter a decline was observed at 270 DAP as observed in

trial I. The mean values of chlorophyll fluorescence for different intervals of time were found to be 0.754, 0.804, 0.833, 0.858, 0.814 and 0.796 at 55, 70, 90, 150, 210 and 270 DAP respectively. The mean performance of treatments indicated that the chlorophyll fluorescence followed the same trend as observed in Trial I with higher chlorophyll fluorescence values in T_9 (0.747), followed by T_{12} (0.727) and T_7 (0.724). Among the treatments T_9 maintained its superiority in chlorophyll fluorescence during all the intervals of time. At 210 DAP, T_9 had significantly increased chlorophyll fluorescence values of 0.905 which was on par with T_{12} (0.876), and T_7 (0.860) during the same stage. As observed in trial I, lower chlorophyll fluorescence value of 0.695 was recorded in T_4.

4.3.6 SPAD index

Time trend of SPAD index as influenced by the chosen treatments and intervals of time of Trial was presented in table 34. The SPAD index increased from 55 DAP to 210 DAP and thereafter a decline was observed at 270 DAP. The mean index of SPAD for different intervals of time were found to be 33.46, 35.12, 36.61, 38.01, 39.33 and 35.87 at 55 70, 90, 150,210 and 270 DAP respectively. The mean performance of the treatments indicated that the SPAD index was higher with T_9 (42.64) followed by T_{12} (41.05) and T_7 (39.66). Among the treatments T_9 recorded the higher SPAD index in all the intervals of time while the lower SPAD index of 32.92 was recorded in T_4.

The influence of the chosen treatments and intervals of time on the SPAD index of Trial II was presented in table 35 .The SPAD index increased from 55 DAP to 210 DAP and thereafter declined at 270 DAP as observed in trial I. The mean index of SPAD for different intervals of time were found to be 34.32, 36.02, 37.45, 38.62, 40.02 and 36.65 at 55, 70, 90, 150,210 and 270 DAPS respectively. The mean performance of the treatments indicated the similar trend as that of trial I with T_9 recording higher SPAD index of 43.59 followed by T_{12} (42.38) and T_7 (38.75). Lower SPAD index of 33.61 was recorded in T_4.

4.3.7 Soluble protein (mg g^{-1})

The soluble protein content increased (Table36) from 55 DAP (11.21) to 270 DAP (19.69). The mean performance of the treatments indicated that the soluble protein content was higher with T_9 (16.68) which was comparable with T_{12} (16.61) and T_7 (15.88) during the same stage. Among the treatments T_9 maintained its superiority in soluble protein content during all the intervals of time. Higher soluble content of 22.50 mg g^{-1} was evident with T_{12} at 270 DAP which was comparable with T_{11} (21.10) during the same stages. Lower soluble protein content of 10.73 mg g^{-1} was observed in control (T_1).

The values of soluble protein content of Trial II are presented in (Table 37). The values of soluble protein content increased from 55 DAP (12.58) to 210 DAP (19.86). The mean performance of treatments followed the same trend of Trial I with higher soluble protein content in T_9 (18.19) which were on par with T_{12} (18.12) and T_7 (17.39). Higher soluble protein content of 24.15 mg g^{-1} was evident with T_9 at 210 DAP which was comparable T_{12} (22.75) during the same stages. Lower mean soluble protein content of 12.24 mg g^{-1} was observed in control (T_1).

4.3.8 Net Photosynthetic rate (µ mol m^{-2} s^{-1})

The influence of the chosen treatments and intervals of time on the photosynthetic rate is presented in table 38 .The net photosynthetic rate increased from 55 DAP (12.25) to 210 DAP (15.16) and thereafter declined at 270 DAP (14.53). The mean performance of the treatments indicated that the photosynthetic rate was higher in T_9 (15.10) followed by T_{12} (14.59) and T_7 (14.45). Treatment T_9 maintained its superiority in photosynthetic rate in all the intervals of time studied with highest net photosynthetic rate of 16.48 µ mol m^{-2} S^{-1} at 210 DAP which was comparable with T_5 (15.55), T_7 (16.00) during the same stage. Lower photosynthetic rate of 13.11µ mol m^{-2} S^{-1} was observed in treatment T_{11}.

Time trend of net photosynthetic rate of trial II as influenced by chosen treatments and intervals of time are presented in table 39 .The photosynthetic rate increased from 55 DAP (12.50) to 210 DAP (15.49) and a decline thereafter at 270 DAP (14.65) was observed as in trial I. The mean performance of the treatments

indicated a similar trend as that of trial I with higher net photosynthetic rate in T_9 (15.37) followed by T_{12} and T_7 (14.75). Treatment T_9 maintained its superiority in net photosynthetic rate in all the intervals of time studied with higher photosynthetic rate of 16.71µ mol m^{-2} S^{-1} at 210 DAP which was comparable with T_{12} (16.48) and T_7 (16.18) during the same stage. As observed in trial I the lower net photosynthetic rate of 13.51µ mol m^{-2} S^{-1} was recorded in treatment T_{11}.

4.3.9 Stomatal conductance (m mol m^{-2} s^{-1})

The influence of the chosen treatments and sampling time on stomatal conductance of trial I is presented in table 40 .The stomatal conductance increased from 55 DAP to 210 DAP and thereafter a decline at 270 DAP was seen. The mean values of photosynthetic rate for different intervals of time were found to be 190.36, 200.84, 213.62, 230.58, 235.56 and 225.82 m mol m^{-2} S^{-1} during 55, 70, 90, 150, 210, and 270 DAP respectively .The mean performance of the treatments indicated a high stomatal conductance in T_9 (234.65) followed by T_{12} (226.75) and T_7 (224.61). Treatment T_9 maintained its superiority in stomatal conductance in all the intervals of time studied with highest stomatal conductance of 256.1 m mol m^{-2} S^{-1}at 210 DAP which was comparable with T_7 (248.60), T_{10} (244.40) and T_5 (241.70) during the same stage. Lower stomatal conductance of 203.65 m mol m^{-2} S^{-1} was observed in $T_{11.}$

The influence of chosen treatments and intervals of time on the stomatal conductance are presented in table 41 .The same trend of stomatal conductance as observed in trial I was seen here also. The stomatal conductance increased from 55 DAP (194.19) to 210 DAP (241.27) and thereafter declined at 270 DAP (227.87).The mean performance of the treatments indicated a similar trend as that of trial I with higher stomatal conductance in T_9 (238.78) followed by T_{12} (229.25) and T_7 (229.20). As observed in trial I treatment T_9 maintained its superiority in stomatal conductance in all the intervals of time studied with highest stomatal conductance of 259.70 m mol m^{-2} S^{-1} at 210 DAP which was comparable with T_{12} (256.10), T_7 (251.40) and T_5 (245.80) during the same stage. Here also treatment T_{11} recorded lower stomatal conductance of 210.95 m mol m^{-2} S^{-1}.

4.3.10 Transpiration rate (m mol m^{-2} s^{-1})

The effect of the chosen treatments and stage of sampling on the transpiration rate of trial I as are presented in table 42 .The transpiration rate increased from 55 DAP (0.414) to 210 DAP (0.522) and thereafter declined at 270 DAP (0.499).The mean performance of the treatments indicated a higher transpiration rate in T_{12} (0.513) followed by T_9 (0.493) and T_7 (0.492). Lower transpiration rate of 0.461 m mol m^{-2} S^{-1} was observed in treatment T_4.

The time trend of various treatments and intervals of time on transpiration rate of trial II is presented in table 43.The transpiration rate increased from 55 DAP (0.424) to 210 DAP (0.528) and declined at 270 DAP (0.497) as observed in trial I. The mean performance of the treatments indicated a similar trend as that of trial I with higher transpiration rate in T_9 (0.522) followed by T_{12} (0.499) and T_7 (0.497). As observed in trial I treatment T_4 recorded lower transpiration rate of 0.456 m mol m^{-2} S^{-1}.

4.3.11 Cation exchange capacity (meq 100g $^{-1}$)

The cation exchange capacity (CEC) in Trial I was found to increase from 150 DAP (16.99) to 270 DAP (18.94) is shown in table 44. The mean performance of the treatments showed that the content was higher with T_9 (20.81) followed by T_{12} (20.15) but the least value (15.40) was evident with control (T_1). Higher CEC of 21.96 was observed with T_9 at 270 DAP which was on par with T_{12} (21.63), T_7 (20.74), T_2 (20.65) T_6 (20.61) during the same stage. Similar trend was shown with the rest of the two stages studied.

The cation exchange capacity of Trial II is shown in Table 45. The cation exchange capacity increased from 150 DAP (17.49) to 270 DAP (20.12). The mean performance of treatments showed the similar trend as observed in Trial I, with T_9 recording higher values of 21.16, followed by T_2 (20.18) and T_6 (20.12), but the least cation exchange capacity values of 16.20 meg. 100g $^{-1}$ was evident with control (T_1). Higher cation exchange capacity values of (23.06) was observed with T_2 at

270 DAP which was on par with T_9 (22.72), T_7 (21.77), T_6 and T_2 (21.65) during the same stage. Similar trend was shown in rest of the stages studied.

4.3.12 Catalase activity (μg H_2O_2 g^{-1} min^{-1})

The effect of chosen treatments and stages on the activity of catalase of Trial I is presented in table 46. The catalase activity showed an increasing trend from 55 DAP (4.86) to 150 DAP (5.47) with another peak at 270 DAP (5.08). The mean performance of the treatments indicated that the catalase activity was higher with treatment T_2 (12.97) followed by T_5 (7.42), T_6 (7.16), T_9 (6.86) and T_{12} (6.64). The treatment T_2 proved its statistical supremacy with higher activity of catalase at all the intervals of crop growth studied. Control (T_1) recorded the lower mean catalase activity of 1.17 μg-H_2O_2 g^{-1} min^{-1}.

The time trend of catalase activity of Trial II as influenced by the chosen treatments and intervals of time was presented in table 47 .The catalase activity showed an increasing trend from 55 DAP(5.01) to150 DAP (5.65) with another peak at 270 DAP (5.15) as observed in trial I . The mean performance of treatments indicated that the catalase activity was higher with treatment T_2 (12.89) followed by T_5 (7.54), T_6 (7.30), T_9 (7.00) and T_{12} (6.84). As in trial I the treatment T_2 proved its statistical supremacy with higher catalase activity at all the intervals of time. As in trial I, lower mean catalase activity of 1.33 μg-H_2O_2 g^{-1} min^{-1} was observed in control (T_1).

4.3.13 Peroxidase activity (Δ 430 nm g^{-1} min^{-1})

The peroxidase enzyme activity of Trial I as influenced by the chosen treatment and intervals of time was presented in table 48. The peroxidase activity showed a linear increase from 55 DAP (1.49) to 270 DAP (2.24). The mean performance of the treatment indicated that the enzyme activity was higher with T_9 (4.04) followed by T_2 (3.89) T_{12} (2.58) and T_5 (2.44) while lower enzyme activity was observed in T_4 (0.59). An increased activity of 4.43 was evident with T_{12} at 270 days after planting. Similar trend was evident in the rest of the stages also. Lower peroxidase activity was observed in T_4 (0.59).

The activity of peroxidase enzyme of trial II as influenced by the chosen treatment and intervals of time was presented in the table 49 .The peroxidase activity showed a linear increase from 55 DAP (1.66) to 270 DAP (2.52) as in trial I. The mean performance of the treatment indicated a similar trend as that of Trial I with higher enzyme activity in T_9 (4.20) followed by T_2 (4.05), T_{12} (2.74) and T_5 (2.61) while lower enzyme activity was observed in T_4 (0.78). An increased activity of 4.68 was evident with T_9 at 270days after planting. Similar trend was observed in rest of the stages also. As in trial I, treatment T_4 recorded lower peroxidase activity of 0.78 Δ 430 $nm.g^{-1}$ min^{-1}.

4.4 Micronutrients

4.4.1 Metabolically active Iron (ppm)

The metabolically active iron content in roots of Trial I as influenced by the chosen treatment and intervals of time was presented in table 50. The metabolically active iron in roots showed an increasing trend from 55 DAP (28.61) to 270 DAP (36.49).An increased metabolically active iron content of 69.50 ppm was observed with T_2 at 270 DAP.A similar trend was also observed at 210 DAP.

The effect of the chosen treatments and stages on the metabolically active iron content in roots of Trial II was presented in table 51 .The metabolically active iron content increased from 55 DAP (29.65) to 270 DAP (37.83) as observed in trial I. An increased metabolically active iron content of 71.59 ppm was observed with T_2 at 270 DAP.A similar trend was also observed at 210 DAP.

4.4.2 Fe/ Mn ratio in root

The Fe / Mn ratio of Trial in roots as influenced by the chosen treatment and intervals of time was presented in table 52. The Fe / Mn ratio were found to decline from 150 DAP (83.72) to 270 DAP (77.88). The mean performance of the treatment indicated that the Fe / Mn ratio was higher with T_1 (112.69) followed by T_{11} (109.54), T_3 (95.81) and T_4 (93.39) while lower Fe/Mn ratio was observed in T_{10} (60.32). Increased Fe / Mn ratio of 116.39 was evident with T_1 at 150 DAP though comparable with T_{11} (112.36) during the same stage.

The time trend of Fe / Mn ratio in roots of Trial II as influenced by the chosen treatments and intervals of time was presented in table 53. As observed in trial I the Fe / Mn ratio was found to decline from 150 DAP (85.48) to 270 DAP (79.23). The mean performance of the treatment indicated that the ratio was higher with T_1 (114.94) followed by T_{11} (111.20), T_3 (98.08) and T_4 (95.27) while lower Fe/Mn ratio was observed in T_{10} (61.36). Increased Fe / Mn ratio of 118.72 was evident with T_1 at 150 DAP though comparable with T_{11} (114.70) during the same stage.

4.4.3 Fe / Mn ratio in soil

Fe / Mn ratio in soil as influenced by the different treatment and intervals of time of trial I was presented in table 54. The Fe / Mn ratio in soil declined from 150 DAP to 270 DAP. The mean values of Fe / Mn ratio was found to be 100.41, 88.94 and 81.76 during 150, 210 and 270 DAP respectively .The mean Fe / Mn ratio was higher with T_1 (126.03) followed by T_{11} (122.44) and T_3 (107.12) while lower Fe / Mn ratio was observed in T_{10} (67.44). The treatment T_1 (139.67) and T_{11} (134.83) were comparable with higher Fe / Mn ratio than the rest of the treatments at 150 DAP.

Fe / Mn ratio in soil as influenced by the different treatments and intervals of time of trial II was presented in table 55. As in trial I the Fe / Mn ratio in soil declined from 150 DAP to 270 DAP. The mean values of Fe / Mn ratio was found to be 101.89, 90.26 and 83.07 during 150, 210 and 270 DAP respectively. The mean values followed a similar trend as that of trial I, with higher mean value with T_1 (127.90) followed by T_{11} (124.28) and T_3 (108.72) while lower Fe / Mn ratio was observed in T_{10} (68.52). The treatment T_1 (141.75) and T_{11} (136.85) were comparable with higher Fe / Mn ratio that the rest of the treatment at 150 DAP.

4.4.4 P/Fe ratio in root

The influence of various treatments on the P/Fe ratio in roots of trial I is presented in table 56. The P/Fe ratio in roots increased from 150 DAP to 270 DAP. The mean values of P/Fe ratio in roots were found to be 0.138, 0.174 and 0.193 during 150, 210 and

270 DAP respectively. The mean performance of treatments indicated that the P/Fe ratio in roots was higher with T_9 (0.207) followed by T_{10} (0.205), T_5 (0.202) and T_{12} (0.197) while lower P/Fe ratio was observed in T_{11} (0.115). Statistically comparable values were registered by T_5 (0.232), T_6 (0.219), T_7 (0.223), T_9 (0.237), T_{10} (0.235) and T_{12} (0.226) but were superior with rest of the treatments at 270 DAP.

The influence of various treatments on the P/Fe ratio in roots of trial II is presented in table 57. The P/Fe ratio increased from150 DAP to 270 DAP. The mean values of P/Fe ratio in roots were found to be 0.155, 0.187 and 0.208 during 150, 210 and 270 DAP respectively. The mean performance of treatments indicated a similar trend as that of trial I, with higher P/Fe ratio with T_{10} (0.247) followed by T_9 (0.223) and T_5 (0.218) while lower P/Fe ratio was observed with T_{11} (0.126).

4.4.5 P/ Fe ratio in soil

P/Fe ratio in soil of trial I (Table 58) indicated that the values increased from 150 DAP to 270 DAP. The mean P/Fe ratio in soil was found to be 0.166, 0.191 and 0.202 during 150, 210 and 270 DAP respectively. The mean performance of treatments indicated that the P/Fe ratio was higher with T_9 (0.229) which was closely followed by T_{10} (0.227), while the P/Fe ratio was least in T_{11} (0.128). The treatment T_9 registered invariability higher P/Fe ratio at all the sampling time.

The P/Fe ratio in soil of trial II (table 59) indicated that the P/Fe ratio increased from 150 DAP to 270 DAP as observed in trial I. The mean P/Fe ratio in soil was found to be 0.168, 0.193 and 0.213 during 150, 210 and 270 DAP respectively. The mean performance of treatments indicated a similar trend as that of trial I, with higher P/Fe with T_9 (0.232) which was closely followed by T_{10} (0.231) while the P/Fe ratio was lower in T_1 (0.154). As in trial I, the treatment T_9 registered invariably higher P/Fe ratio in the soil at all the stages of sampling.

4.5 Yield parameters

4.5.1 Number (lakh ha^{-1}), weight (Kg) and height (cm) of millable cane

The influence of various treatments on number, weight and height of millable canes are presented in table 60. Significant differences in the number of millable canes (NMC) were observed among the various treatments in trial I. Higher NMC was recorded in T_9 (1.03) which was closely followed by T_{12}, T_7 and T_1 (1.00). Lower NMC of 0.95 lakhs $ha^{-1}$was recorded in control. Height and weight of millable canes followed the same trend as that of NMC.

The influence of various treatments on number, weight and height of millable canes of trial II are presented in table 61 .Significant differences in the number of millable canes (NMC) as seen in trial I was observed in trial II also. NMC followed a similar trend as that of trial I, with higher NMC in T_9 (1.045) and closely followed by T_{12} (1.028), T_7 (1.019) and T_2 (1.015). Height and weight of millable canes followed the same trend as that of NMC observed in trial I.

4.5.2 Cane girth (cm), number and average length of internodes (cm)

Significant differences among the treatments were observed with respect to cane girth in trial I (Table 62). The cane girth and number of internodes followed the same trend as that of number of millable canes. However, little variation was observed in the average length of internodes among various treatments and they were not statistically significant. Nevertheless, T_9 proved its supremacy with increased values for cane girth (2.99) and number of internodes (22.00).

Effect of various treatments on cane girth (cm), number of internodes and average length of internodes of trial II is presented in table 63. The cane girth and number of internodes followed the same trend as that of number of millable canes. Very little variation was observed in the average length of internodes among the various treatments as seen in trial I. In trial II also, T_9 proved its supremacy with increased vales for cane girth (3.07) and number of internodes (22.98).

4.6 Juice quality parameters

The brix per cent, pol per cent, purity co-efficient, reducing sugar and commercial cane sugar (CCS %) was estimated for different treatments at harvest.

The effect of various treatments on the juice quality parameters of trial I was presented in table 64. Highest brix (%) was noticed in T_9 (23.21) which was closely followed by T_{12} (22.81) and T_7 (22.27). Higher pol per cent was observed in T_9 (21.04) which was closely followed by T_{12} (20.10) and T_7 (12.86). There was not much variation in purity co-efficient as influenced by the chosen treatments and the values were statistically non-significant. The reducing sugar was found to be lower in T_7 (0.36) and was closely followed by T_9 (0.37). Significant differences were observed with respect to CCS % among the chosen treatments. Higher CCS% was observed in T_9 (13.90) followed by T_{12} (13.70) and T_7 (13.49).

The effect of various treatments on the juice quality parameters of trial II was presented in table 65. The brix (%) followed the same trend as observed in trial I with highest brix in T_9 (23.45) and closely followed by T_{12} (23.04) and T_7 (22.50). Higher sucrose percent was noticed in T_7 (21.25) which was closely followed by T_9 (20.28) and T_2 (20.06). Not much variation was observed in purity co-efficient as influenced by the chosen treatments and the values were statistically non-significant as in trial I. Reducing sugar was found to be lower in T_9 (0.37) and was closely followed by T_7 (0.39). Significant variations were observed with respect to CCS % among various treatments was observed in trial II also. Higher CCS % was observed in T_9 (15.94) followed by T_{12} (14.15) and T_7 (13.93).

4.7 Cane yield (t ha^{-1}) and sugar yield (t ha^{-1}).

Effect of various treatments on the cane and sugar yield at harvest of trial I is presented in table 66.The cane yield in trial I was higher in T_9 (121.11) followed by T_{12} (116.55) and T_7 (110.11). The sugar yield was also higher in T_9 (16.83) followed by T_{12} (15.47), T_7 (15.36).

The influence of various treatments on the cane and sugar yield at harvest of trial II is presented in table 67. The cane and sugar yield followed a similar trend as observed in trial I with higher value in T_9 (121.10) followed by T_{12} (14.83).

4.8 Correlation studies

4.8.1 Association among the morpho-physiological, physiological / biochemical and yield attributes

4.8.2 Association among morpho-physiological characters and cane yield as influenced by the chosen treatments (Table 68)

The phenotypic correlation analysis of morpho-physiological characters indicated that the characters like LAI ($r = 0.834^{*}$), LAD ($r = 0.852^{*}$), CGR ($r = 0.952^{**}$) and NAR ($r = 0.965^{**}$) showed higher degree of positive association with cane yield. Nevertheless the character SLW did not attain statistical significance with yield.

4.8.3 Association among physiological / biochemical characters and cane yield as influenced by the chosen treatments (Table 69)

Among the biochemical parameters observed the characters such as photosynthetic rate ($r = 0.648^{**}$), SPAD ($r = 0.789^{**}$), chlorophyll 'a'($r = 0.527^{**}$), soluble protein ($r = 0.736^{**}$), Fv/Fm ($r = 0.739^{**}$), P/Fe (Root) ($r = 0.815^{**}$), metabolically active iron ($r = 0.785^{**}$), and cation exchange capacity of roots($r = 0.892^{**}$) showed highly significant positive association with cane yield. Nevertheless, parameters such as total chlorophyll ($r = 0.407^{*}$) exhibited less significant association with yield. But chlorophyll 'b' showed no correlation with cane yield.

4.8.4 Association among yield attributes and cane yield as influenced by the chosen treatments (Table 70)

The cane yield was significantly and positively correlated with yield attributes like cane girth ($r = 0.846^{**}$), cane height ($r = 0.900^{**}$), number of internodes ($r = 0.700^{**}$), number of millable canes ($r = 0.666^{**}$), average length of internodes ($r = (0.678^{**}$), CCS ($r = 0.528^{**}$) and sugar yield ($r = 0.975^{**}$). However tillering capacity did not show association with cane yield.

4.9 Benefit Cost ratio (Table 71)

The highest net return of Rs.1.27 for a rupee spent was obtained in T_9 (1 %$FeSO_4$ + 0.5 % $ZnSO_4$+ 0.5 % $MnSO_4$ + 1 ppm Brasssinolide). A BCR of 1.20 was obtained in T_{12} (Soil application of Micronutrient mixture @ 5 Kg + 1 ppm Brasssinolide + 150 ppm Salicylic acid spray) followed by T_{10}(1 %$FeSO_4$ + 0.5 % $ZnSO_4$+ 0.5 % $MnSO_4$ +1 ppm Brasssinolide +150 ppm Salicylic acid) 1.19 which was comparable with T_7 (1 % $FeSO_4$+ 0.5 % $ZnSO_4$ +0.5 % $MnSO_4$). Lowest net return of 0.89 for a rupee spent was obtained with (T_1) control followed by T_8 (1 ppm Brasssinolide + 150 ppm Salicylic acid) 0.99 and T_3 (1 ppm Brasssinolide) 0.97.

CHAPTER V

DISCUSSSION

The results of the field experiments conducted to study the effect of iron nutrition on the morphological, physiological, biochemical and yield and its attributes as well as juice quality characteristics of sugarcane variety Co 86032 grown in two locations during 2007 are discussed in this chapter.

5.1 Influence on morpho-physiological characters

5.1.1 Germination percentage

Sett germination in sugarcane is mainly governed by age of seed cane, environmental factors particularly temperature, relative humidity and soil moisture. In the present study, the treatments were imposed only after assessing the germination per cent at 40 DAP hence the effect of treatments on the germination per cent was non-significant.

5.1.2 Tillering capacity

Tillering capacity is an important character in sugarcane as it is directly related to final millable cane production at harvest.Tillering in sugarcane is a genetic character. However, several studies have indicated that it could be altered to a certain extent by environmental factors such as soil moisture, nutritional status and cultural techniques besides atmospheric temperature (Clements, 1980). In the present study in trial I, the treatment T_9 (foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm Brasssinolide) recorded the higher tillering capacity of 1.67 lakhs ha^{-1} which was 7.78, 10.18 and 22.15 per cent higher than that of $T_{12,}$ T_7 and T_1 respectively (Fig. 3). Similar results were obtained in trial II also (Fig. 4). The results were in accordance with the findings of Nayyar *et al*.(1984), who studied the response of sugarcane to zinc and iron sources and reported that the yield attributing characters viz., number of tillers, millable cane per stool and cane yield were increased. Yadav *et al*. (1987) reported that foliar application of ferrous sulphate, manganese sulphate, zinc sulphate and copper sulphate improved the morphological characters.

Increased tillering capacity due to foliar feeding of zinc sulphate was also reported by Kumaresan *et al*. (1989).

5.1.3 Shoot population

Shoot population is an important character in sugarcane which is directly correlated with the cane yield. In the present study T_9 recorded higher shoot population of 1.88 lakhs ha^{-1}in trial I, which was 11.17 per cent more than control (T_1). Trial II also followed a similar trend as that of trial I with T_9 recording 15.6 per cent increased shoot population of 1.90 lakhs ha^{-1} over control (T_1) which recorded 1.64 lakhs ha^{-1} only. The results were in accordance with the findings of Anon (1983) reporting a considerable increase in size and yield attributing characters viz., tillers per stool, shoot population, plant height, length and girth of internodes with application of micronutrients of Fe, Cu, Mn and B. Banger *et al*. (1991) also reported that all the growth and yield contributing characters were benefited by the application of various levels of zinc and iron. Sen *et al.* (1985) applied zinc, manganese and iron alone and in all combinations using FYM as micronutrient carrier. They observed that B, Mn and Fe applied alone or in combination significantly improved the cane yield, CCS per cent, number of tillers per plant, shoot population, number of millable canes per stool, plant height, length and girth of internodes and sugar yield. Palanivel (1990) reported that foliar spray of 1.5 % ferrous sulphate, 1 % zinc sulphate and 1 % urea solution increased all the yield and yield components. Similar improvement in shoot population was reported by Jayabal *et al*. (1991) due to application of zinc sulphate. Wang *et al*. (2005) reported 12 per cent increase in shoot population with foliar application of zinc sulphate.

5.1.4 Single cane dry weight

Similar to the population of shoot, dry weight of single cane is also an important parameter in sugarcane which is directly related to millable cane production at the time of harvest. In the present study, T_9 recorded higher single cane dry weight of 604.51 g $plant^{-1}$ which was 6.23, 9.43 and 25.42 per cent higher than that of T_{12}, T_9 and T_1 respectively. Significant influence on foliar application of ferrous sulphate on single cane dry weight at earlier stages might be attributed to enhanced vegetative growth. The ferrous form of iron

applied through foliage would have been utilized by the chloroplast essential in the formation of chlorophyll and helped in increased photosynthetic activity and accumulation of dry matter especially the green foliage of the plants (Sen and Samad, 1975).

5.2 Influence on physiological and biochemical characters

5.2.1 Leaf Area Index

The canopy photosynthesis largely depends on the Leaf Area Index (LAI) and canopy structure which in turn contributes to dry matter production. This is one of the principal factors which influence canopy photosynthesis (Hansen, 1972). A steady increase in the LAI was observed in trial I during the sampling intervals irrespective of the treatments. In the present study foliar spray of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ +1 ppm Brassinolide recorded higher LAI and was 6.06, 12.23, and 24.23 per cent higher than T_{12}, T_7 and T_1 respectively. Similar results were obtained in trial II also. Increased LAI values obtained with foliar spray of $FeSO_4$ might be due to the fast and speedy entry of iron which rectified the chlorosis. Its involvement in the synthesis of chlorophyll would have directly helped in increased green leaf surface area. Similar results were reported by Kanagaraj and Ramanathan (1981). Increase in LAI may also be due to the specific role played by zinc in the plant metabolism particularly in the synthesis of IAA which is essential in the growth and development of plant parts and provides a large photosynthetic area of leaves for longer duration since IAA inhibits chlorophyll degradation. The IAA is a component of various enzymes such as carbonic anhydrase and alcohol dehydrogenase possessing suggestive role in chlorophyll formation, photosynthesis and metabolic reactions in the plants leading to higher LAI (Reddi Ramu *et al.*,2007).Exogenous application of Brassinolide, being a component of the treatment, might have helped in better rooting, enhanced uptake of more nutrients and initiation of various physiological and biochemical processes leading to the increased morphological and growth parameters like leaf area, number of leaves, plant height, Specific Leaf Weight (SLW), Crop Growth Rate (CGR), and Relative Growth Rate (RGR) (Prakash *et al.*, 2007).

5.2.2 Crop Growth Rate

The Crop Growth Rate (CGR) is considered as the efficiency of the crop to accumulate biomass per unit land area. Besides, it is also an interaction between NAR and LAI as reported by Bhardwaj *et al*. (1987).The trend of values manifested treatment differences recording increased CGR of 14.08 g m^{-2} day $^{-1}$ due to foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide, while lower CGR of 7.72 g m^{-2} day $^{-1}$ was recorded in untreated control (T_1).In trial I the best treatment T_9 (1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ and 1 ppm brassinolide) recorded 31.84, 20.75 and 31.59 per cent higher CGR than that of T_7, T_{12} and T_2 respectively. Similar trend was observed in trial II also with highest CGR observed in T_9 (1% $FeSO_4$ + 0.5 % $MnSO_4$ +0.5 % $ZnSO_4$ and 1 ppm Brassinolides) which was 20.16, 11.78 and 28.44 per cent higher than T_7, T_{12} and T_{10} respectively. This increased CGR might be due to the presence of zinc in the treatment. Zinc is related to the synthesis of auxin to a large extent as first suggested by Skoog (1940). Hence, foliar feeding of zinc as zinc sulphate would have increased the values of CGR through auxin metabolism. Prakash *et al*.(2007) reported increased morphological and growth characters like plant height, number of leaves, SLW, CGR, NAR and RGR contributed to the higher dry matter. In addition, foliar application of brassinolide might have resulted in enhanced uptake of nutrients and initiation of various physiological/ biochemical processes ultimately leading to increased morphological and growth parameters. These results were in line with the findings of Yadav (1998) reporting similar improvement in all the growth parameters viz., CGR, LAI, NAR, and dry matter at all the stages of growth due to foliar feeding of iron as ferrous sulphate.

5.2.3 Relative Growth Rate

Relative Growth Rate (RGR) expresses the dry weight increase in a time interval in relation to the initial dry weight. In the present study in trial I, the RGR also showed similar trend as that of CGR. Among the treatments, foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide showed higher RGR values (17.36). The RGR increased from 55 to 150 DAP and declined thereafter. Similar trend was observed

by Yadav *et al*. (1979). This decrease in RGR might be due to the senescence of lower leaves as the crop progresses in age. As zinc is one of the components of the treatment, foliar feeding of zinc might have increased the RGR through auxin metabolism. Yet another reason for increased RGR might be due to the foliar application of brassinolide, which might have helped in better uptake of nutrients by producing efficient root system. As a result, all the physiological/biochemical parameters have been increased ultimately leading to the increased RGR (Prakash *et al*., 2005).

5.2.4 Net Assimilation Rate

The rate of accumulation of dry matter per unit leaf area/weight is the measure of the photosynthetic efficiency of crops (Watson, 1958) and it is likely to have a positive relationship with final total dry matter accumulation. In the present study, an increasing trend of NAR was observed irrespective of the treatments till 210 DAP and later on a decerase was noticed in trial I. Higher NAR of 38.40 mg cm^{-2} day^{-1} was recorded in foliar spray of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide and this was 4.63 and 6.69 per cent higher than T_{12} and T_7 respectively. Lower NAR (25.49) was recorded in untreated control (T_1). Similar observations were recorded in trial II also. The higher NAR at early stages might be due to the rapid vegetative growth and utilizing the already existing assimilates to the sink at later stages. The decrease in NAR after 210 DAP might be due to losses during respiration in all the plant parts (Briggs *et al.,* 1920).Yet another reason for increased RGR might be due to the accumulation of dry matter with increased photosynthetic efficiency as ferrous sulphate was one of the components of the treatment.

5.2.5 Specific Leaf Area

The Specific Leaf Area (SLA) reflects the thickness of the leaf and relative proportion of conductive tissues. In both the trials, SLA was found to increase from 55 DAP to 270 DAP. Higher SLA in trial I during the grand growth period might be due to the fact that biomass added to leaf is maximum. In the present study all the treatments improved the values of SLA. Higher SLA of 159.04 cm^2 mg^{-1} was recorded with the foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide and

lower in the foliar application of 150 ppm salicylic acid. Trial II also recorded identical results. Similar results were reported by Yadav (1998).

5.2.6 Specific Leaf Weight

Specific Leaf Weight (SLW) is considered as a positive reliable index for improving the yield of crops. It indicates the quantity of metabolites accumulated per unit leaf area. In the present study, the SLW in trial I showed a linear decrease from 55 to 270 DAP irrespective of the treatments. The decline in SLW might be attributed to the rapid translocation of assimilates to the developing sink (Imsande, 1989). All the treatments increased the values of SLW. Among the treatments foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide recorded an increased value of SLW of 8.12 mg cm^{-2} which was 2.53, 4.64, and 10.93 % increase over T_{12}, T_8 and T_7 respectively. Similar trend was observed in trial II also. Increased values of SLW by foliar application of ferrous sulphate and 0.1% citric acid were reported by Kumavat *et al*. (2005). Increased values of SLW might also be due to the foliar application of brassinolide as reported by Prakash *et al*. (2007). This might be due to the better rooting which in turn increased the uptake of nutrients and aided in the initiation of physiological/biochemical processes leading to increased morphological and growth parameters viz., CGR, RGR and NAR. The positive effect of brassinolide on SLW was obtained through enhancement of phloem transport and its probable role in membrane permeability, (Krizek and Mandava, 1983).The higher values of SLW observed in the treatment could be due to the anatomical changes in the leaves, such as thicker epidermal cells and increase in the size of spongy mesophyll cells rather than the increase in the number of cell layers as observed in citrus (Zekri *et al*., 1990).

5.2.7 Leaf Area Duration

Leaf Area Duration (LAD) is an important factor to enhance the growth and development of a crop (Evans, 1975). It is a measure of duration of photosynthetic apparatus by which it accumulates the dry matter for growth and development (Wetblank *et al*,, 1966).The trend of results in both the trials showed that LAD increased from 55 to 270 DAP irrespective of the treatments. Among the treatments, foliar application of 1%

$FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide recorded higher LAD of 183.84 days followed by T_{12} (161.06) and T_7 (155.88). Foliar feeding of zinc as zinc sulphate recorded significantly higher LAD in wheat (Kumar *et al.*, 2004). Exogenous application of brassinolide helped in better rooting, enhanced uptake of nutrients and regulated the supply of nutrients as well as assimilates, which might have attributed to the maintenance of leaf greenes for a longer time thus increasing the LAD. (Prakash *et al*., 2007)

5.2.8 Chlorophyll fractions

Both the fractions as well as total chlorophyll content showed an increasing trend in trial I up to 210 DAP and declined thereafter. In general, all the treatments recorded higher chlorophyll content compared to the control (T_1). Foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ +1 ppm brassinolide recorded higher content of chlorophyll fractions and also total chlorophyll content (Fig. 5) followed by T_{12} and T_4. Similar trend was observed in trial II with respect to chlorophyll fractions and total chlorophyll content also (Fig.6). Increased chlorophyll content due to foliar spray of ferrous sulphate could be due to the increased biosynthesis or due to the healthy development and assembly of chlorophyll (Abadia and Abadia, 1993; Chen and Barak, 1962). Iron is directly involved in chlorophyll biosynthesis through condensation of glycine and succinyl CoA to form amino levulinic acid (ALA) the precursor of porphyrin (Marsh *et al.*, 1963). Increased chlorophyll content by foliar application of manganese has been reported due to enrichment of ultra structure of the thylakoids as a consequence of promotion of carotenoid biosynthesis (Polle *et al.*, 1992). Tripathy *et al*. (1999) reported increased chlorophyll content in soybean due to zinc application as zinc sulphate might have helped for the biosynthesis of chlorophyll. Kulaeva *et al*. (1991) reported that brassinolide induced increase in chlorophyll content in plants which could be attributed to increase in enzyme protein.

5.2.9 Chlorophyll a/b ratio

It is difficult to explain how foliar application of ferrous sulphate increased the chlorophyll a/b ratio. Pushnic and Miller (1989) found that probably application of iron

as ferrous sulphate regulated the PS I development by direct regulation of low molecular protein containing possibly non-heme protein required for the system assembly. In the present study of trial I, a steady increase in chlorophyll a/b ratio was observed. Foliar feeding of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide recorded higher chlorophyll a/b ratio of 2.96 followed by T_3 and T_7 (2.83). Lowest chlorophyll a/b ratio was observed in the treatment of T_{10} (2.65).Similar trend was observed in trial II also.

5.2.10 SPAD index

The SPAD index indicates the amount of chlorophyll in the leaves quantitatively. It determines the relative amount of chlorophyll by measuring the transmittance of the leaf in two wave length region- red and near infra red regions. The meter calculates a numerical SPAD index which is proportional to the amount of chlorophyll present in the leaf. A higher SPAD index indicates high chlorophyll content. A decrease in SPAD index indicates a decrease in chlorophyll content. On site measurements of leaf chlorophyll content is better than the usual spectrophotometric procedure due to its higher speed, lower cost with very little destruction of plants materials (MacNicol *et al.*, 1976).

Among the treatments of trial , foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide recorded higher SPAD index of 43.59 which was 3.76, and 7.84 per cent higher than T_{12} and T_7 respectively (Fig. 7). Similar trend was seen in the second trial also (Fig. 8). Ranferi Maldonado – Torres *et al*. (2006) observed that SPAD index decreased as severity of Fe chlorosis increased. Reyes *et al*. (2006) reported that the SPAD index is highly correlated with the chlorophyll content per leaf.

5.2.11 Chlorophyll fluorescence

The chlorophyll fluorescence allows to study the different functional levels of photosynthesis indirectly, primary light reactions, thylakoid, electron transport reactions, dark enzymatic stroma reactions, slow regulatory processes and the effects of environmental stresses on plants. Photosynthesis is often reduced in plants experiencing adverse conditions such as water deficit, temperature, nutrient deficiency, polluting agents and attack by pathogens. In green leaves, about 90 per cent of the emitted

chlorophyll fluorescence at 658 nm is reabsorbed by the chlorophyll of the leaf (Gitelson *et al.*, 1999). In the present study of both the trials, foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ +1 ppm brassinolide recorded higher values of 0.747 followed by T_{10} (0.738) (Fig.9&10). Similar observations of higher chlorophyll fluorescence were reported by James A. Guikema (1985) and Pushnik *et al*. (1989).

5.2.12 Net Photosynthetic rate

Photosynthetic efficiency is the primary component of dry matter accumulation. It has however been found to be consistently related to the economic yield because of several factors like photorespiration, dark respiration, assimilate transport and its partitioning efficiency, filling duration and sink components. Crop productivity in general depends on the net photosynthetic rate and canopy architecture of the crop. Dry matter accumulation is the result a balance between photosynthetic activity and respiratory loss in any autotrophic plants. Net photosynthetic rate showed increasing trends up to 210 DAP and declined thereafter. Among the treatments of trial I, foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide was better in registering high net photosynthetic rate. Similar results were obtained in trial II. This is in line with the findings of Nenova *et al*. (1993) who reported increased photosynthetic rate of Maize seedlings with the addition of 7.5 mg Fe/L to the Hoagland nutrient solution.

Application of iron reduces the chlorotic condition of leaves and a good correlation exists between iron content and chlorophyll content of leaves. A major portion of the iron is located in the chloroplasts and iron has been shown to have essential role in photosynthesis. Iron is necessary for synthesis of α-amino levulinic acid, a precursor of chlorophyll. Increase in photosynthetic rate might also be due to higher chlorophyll a/b ratio present the leaves. The results are in conformity with the findings of Black and Mayne (1970) who reported that the plants efficient in carbon dioxide assimilation have higher chlorophyll a/b ratio. Foliar application of ferrous sulphate increased the content of light harvesting pigments (Morales *et al*., 1994). The increase in photosynthetic rate might also be attributed to the role played by zinc in plant metabolism particularly in the synthesis of auxins which is required for growth and development of

plants. Increase in chlorophyll ‘a’ and ‘b’ is responsible for healthy growth which triggered larger photosynthetic rate for longer duration.

The increase in photosynthesis might be due to the increase in SLW exhibiting a strong positive association with leaf photosynthesis (Bowes *et al.,* 1972) in the treated plants. Terry and Abadia (1986) reported increased photosynthetic rates as a result of increased photochemical activity of the chloroplast which is a consequence of increased number of reaction centers and electron carriers associated with the gain of thylakoids per granum (Spiller *et al.,* 1980), increase in photosynthetic electron transport rate (Raven *et al.*, 1999), and in the light harvesting pigments (Morales *et al.*, 1994) by foliar application of iron. Jing Quan Yu *et al*. (2004) also stated that brassinolide treatment in *Cucumis sativus* resulted in large increase in the photosynthetic capacity of the leaves.

5.2.13 Transpiration rate

Transpiration, the major process involving water loss was found to be influenced by foliar spray of micronutrients viz., iron, manganese and zinc and plant growth regulators such as brassinolide and salicylic acid. Among various treatments, T_{12} recorded higher transpiration rate of 0.513 m mol m^{-2} S^{-1}, closely followed by T_9 (1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide) which recorded 0.493 m mol m^{-2} S^{-1}, followed by T_7 (1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$) with 0.492 m mol m^{-2} S^{-1}. Rombala *et al*. (2005) reported that sugar beet plants grown in solution culture devoid of iron had an adverse effect on plant growth, leaf chlorophyll, and net photosynthesis. However, transpiration rate was only partially reduced, which suggested that iron deficiency does not trigger a signal of stomata closure but depresses the RUBP carboxylation activity, thus causing an increase in the intermediates CO_2 concentration. Maintaining a normal water flow through stomata could represent a mechanism of temporary adoption of sugar beet plants under iron deficiency. Thus the present findings contradicted to the findings of DeKock *et al*. (1981) who reported that iron deficit plants might suffer from water loss by increased transpiration.

5.2.14 Stomatal conductance

Stomatal conductance is the measure of ability of the plant to allow for gaseous exchange from the external environment. In the present study, irrespective of the treatment, there was increases in the stomatal conductance from 55 to 210 DAP. Among the treatments, foliar feeding of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide registered increased stomatal conductance of 238.78 m mol m^{-2} s^{-1}, while foliar spray of salicylic acid recorded lower value of 208.23 m mol m^{-2} s^{-1}.Similar observations were recorded in both the trials. The results were in accordance with the findings of Vassilios Chouliaras *et al*. (2004) who reported greater net photosynthetic rate and stomatal conductance in citrus with foliar application of 20 µM Fe-EDDHA as iron source. Similar results were also observed by Terry (1984) in sugar beet where iron deficiency caused a decline in stomatal conductance. This suggested a loss of stomatal control mechanism under iron deficient situations (Davis *et al*., 1986).

5.2.15 Soluble protein

In the present investigations, soluble protein was conditioned by iron, manganese and zinc supply through foliar spray. Combination of these treatments along with brassinolide (T_9 and T_{12}) was highly effective in improving the protein status of the sugarcane leaves. The treatment T_9 reported higher soluble protein content of 18.19 mg g^{-1} which was closely followed by T_{12} (18.12). The next best treatment included foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$. The trend was similar in both the trials (Fig.11& 12). The improved protein status might also be due to the presence of brassinolide. This was supported by the findings of Sairam (1994) who reported that 0.1 ppm homobrassinolide application increased the soluble protein content in wheat plants. The increased soluble protein could also be due to the enhanced activation of RUBP carboxylase. Vardhini and Rao (1998) reported that increased soluble protein in groundnut by brassinolide spray was associated with enhanced nucleic acid levels. The results were in conformity with the findings of Bindu, (2000) who observed significant increase in RNA and DNA polymerase activity and the synthesis of RNA, DNA and soluble protein in groundnut. This suggested the involvement of brassinolide in transcription and replication leading to increase in enzyme activities during tissue growth.

This might be the reason for increased soluble protein content in sugarcane leaves in the present study.

5.2.16. Cation Exchange Capacity

The Cation Exchange Capacity (CEC) of the roots was known to influence the absorption of cations by plant roots (Singh and Ram, 1973). Foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ +1 ppm brassinolide recorded higher mean CEC values of 20.81 meq 100 $g^{-1}$of roots, followed by T_{12} (20.15) and T_7 (19.67), while lowest CEC of 15.40 meq 100 $g^{-1}$of roots was observed in untreated control (T_1) in trial I (Fig. 13). Similar trend was observed in trial II (Fig. 14).The enhanced CEC of the roots might be due to the beneficial role of iron and zinc in the treatment. Cinelli F. *et al*. (1995) reported that foliar application of iron to root stocks of *Prunus cerasifera* helped in alleviating iron chlorosis. This could be attributed to the physiological role of iron in chlorophyll formation and its stimulatory effect on the various metabolic processes of the plant leading to improvement of CEC and there by increased nutrient absorption where by it corrected iron chlorosis.

5.2.17 Catalase

The enzyme catalase is considered as an antioxidizing agent and scavenging enzyme since it protects the crop from damage caused by the accumulation of free radicals which affect the membrane system under different types of stress (Casano *et al*., 1999). The activity of the enzyme was affected in Fe- deficient and other stress conditions (Shrivastava *et al.*, 2004). In the present investigation for trial I, foliar application of 1% $FeSO_4$ recorded highest catalase enzyme activity of 13.37 μg H_2O_2 g^{-1} min^{-1} followed by foliar spray of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide which registered enzyme activity of 8.12 μg H_2O_2 g^{-1} min^{-1}. T_5 (1% $FeSO_4$ + 0.5 % $ZnSO_4$) also recorded higher catalase activity of 8.08 μg H_2O_2 g^{-1} min^{-1} followed by T_6 (1% $FeSO_4$ + 0.5 % $MnSO_4$) which recorded 7.96 μg H_2O_2 g^{-1} min^{-1}. (Fig.15) Trial II also recorded similar results (Fig. 16). Similar results were obtained in soybean (Brown *et al*., 1952), barley (Agarwala *et al*., 1964), maize and radish (Agarwala *et al*., 1965).

Foliar spray of iron as ferrous sulphate increased the catalase activity and also the chlorophyll content pea plants (Del Rio *et al*., 1978). Similar effect of iron spray on catalase and chlorophyll might be probably due to the existence of a common precursor in the biosynthesis of porphyrin ring of chlorophyll and the heme part of catalase as demonstrated in cowpea plants by Marsh *et al*. (1963). Higher catalase activity was also due to the foliar application of manganese (Bailey *et al*., 1944). It is therefore, probable that manganese through the direct influence on the iron containing prosthetic group controlled the catalase activity.

5.2.18 Peroxidase

Peroxidase is a key enzyme involved in metamorphogenesis and auxin oxidation. It is also an antioxidant enzyme involved in scavenging of H_2O_2 (Shigeoka *et al*.,2002).Like catalase, peroxidase activity was also found to be higher in trial I (4.04) due foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide followed by 1% $FeSO_4$ treatment (3.89). Like catalase activity treatment, T_5 (1% $FeSO_4$ + 0.5 % $ZnSO_4$) also recorded higher peroxidase activity (2.44) followed by T_{10} (1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide and Salicylic acid) which registered an increased enzyme activity (2.32). Similar results were observed in trial II. The above results were in conformity with the findings of Vassilious Chouliaras *et al.* (2004) who reported decrease in catalase activity in citrus grown under iron deficient condition. Increased activity of catalase and peroxidase were obtained on 60 DAS in sesame treated thrice with 28-epibrassinolide (Prakash *et al*., 2007). The results confirmed that foliar feeding of iron generally resulted in increase in specific activities of all the Fe enzymes viz., catalase, peroxidase and superoxide dismutase. (Mehrotra *et al*., 1990).

5.2.19 Metabolically active iron

The total amount of iron in a leaf does not give a good indication of the adequacy of the element for healthy growth, as leaves showing chlorosis might contain as much or even more iron than healthy leaves (Bennet, 1945). The fraction of the iron which could be extracted by normal HCl from dried leaf material gives a better indication of the iron status (Oserkowsky, 1933). This fraction was termed as ‘metabolically active iron’ as it

was thought to participate in chlorophyll formation. The metabolically active fraction of iron in plants has been considered as a correct estimate of true iron status of the plant (Agarwala *et al*., 1976; Patel *et al*., 1977; and Takkar and Kaur, 1983).

In the present study, foliar application of iron as ferrous sulphate either singly or in combination with micronutrients of manganese and zinc and growth regulators like brassinolide and salicylic acid helped in increasing the metabolically active iron. Among the various treatment in trial I foliar spray of 1 % $FeSO_4$ (T_2) registered higher active iron of 43.69 ppm followed by T_{12} (43.21), T_9 (37.69) and T_{10} (36.04) (Fig.17). Similar trend was seen in the second trial (Fig. 18). Mehrotra *et al*. (1990) reported increase in chlorophyll content, active iron and dry matter yield content in maize following foliar feeding of iron. In the light of the role played by iron in maintenance of chlorophyll in plants (Naik and Joshi, 1979), the observed increase in the metabolically active fraction of iron in T_2 confirms the involvement of iron the biosynthesis of chlorophyll. Studies conducted by Mengel *et al*. (1984) revealed no correlation between chlorophyll and total iron. In contrast, there was correlation between chlorophyll and metabolically active iron (Abadia *et al*., 1985). In the present study a good correlation value ($r = 0.411^{*}$) was found between total chlorophyll and metabolically active iron.

5.2.20 Fe / Mn ratio (Root and Soil)

Several indexes were used to determine the iron nutritional status of plants. The importance of a balance between available iron and manganese in roots and soil has been emphasized by Shive (1941). For a normal and healthy growth of soybean, balance between iron and manganese is important (Somers and Shive, 1942). Lindner and Harley (1944) suggested that Fe / Mn balance in the tissues (roots) and soil is of great importance for the well being of the plants. The interrelationship between Fe / Mn in the plants and soil is important for plant growth. In the present study in trial I foliar application of micronutrients of iron, manganese, zinc and growth regulators like brassinolide and salicylic acid reduced the Fe / Mn ratio in both root and soil, while untreated control (T_1) registered maximum Fe / Mn ratio of 112.69 and 126.03 in roots and soil respectively (Fig. 19). Similar trend was seen in trial II (Fig.20). The results revealed that in untreated control (T_1) and also in T_{11} i.e., soil application of 5 kg

micronutrient treatments, the Fe / Mn ratio was two to three times higher than rest of the treatments. Lowest Fe /Mn ratio were recorded in the treatment which included 1.88 µ g ml^{-1}as iron as EDTA + 0.82 µ g ml^{-1} Mn + 0.07 µ g ml^{-1}+ Cu and 0.16 µ g ml^{-1} Zn (Lucena *et al*., 1990). A wide Fe to Mn ratio was observed in all the tissues of chlorotic plants, the wider Fe to Mn ratio can be taken as an index for diagnosing lime induced chlorosis (Tandon and Srivastava, 1981). Similar results were recorded by Izaguirre-Mayoral and Sinclair (2005). The ratio changed according to the age of the crop and decreased as the crop matured.

5.2.21 P / Fe ratio (Root and soil)

Uptake of elements of phosphorus, iron, potassium and calcium are interrelated in roots and soil in such a way that, increase or decrease of one ratio i.e., P/ Fe led to corresponding increase or decrease in the other. (De Kock *et al*., 1960). In the present study, foliar application of iron, manganese, zinc and growth regulators of brassinolide and salicylic acid influenced the P / Fe ratio. Lower P /Fe ratios were registered when the micronutrients of iron, manganese and zinc were sprayed in trial I (Fig.21). In the untreated control higher P / Fe ratio was recorded. Similar results were recorded in trial II. (Fig.22). The results confirmed the earlier findings of Abadia *et al*. (1985) who recorded decreased P / Fe ratio when trunk injection of iron was given in peach trees. Similar results were obtained in grapevine, wherein increased chlorophyll levels related to decrease in P / Fe ratios (Bavaraesco *et al*., 1992).

De Kock *et al*. (1960) suggested that high P / Fe ratios in sugarcane are suggestive of iron deficiency. They further reported that there was a highly significant linear relationship between active iron fraction and P / Fe ratio (De Kock *et al*., 1979). Ranferi Maldonado-Torres *et al*. (2006) reported that the severity of Fe chlorosis in Mexican lime leaves was associated with a significant increase in the concentrations of K, total Fe, Mn and P/Fe ratios. The present investigation comparing the balance of these cations has yielded similar interesting results. The results in both the trials, further show the intensity of iron chlorosis in sugarcane has a definite correlation with ionic balance between P / Fe as this ratio showed a linear increase in untreated control plots where chlorosis was observed. A drop in the ratio of P / Fe was due to the change in the ion uptake pattern

following foliar feeding of ferrous sulphate. Similar observations were observed by Bavaresco *et al.* (1992) in grapevine seedlings.

5.3 Influence on yield attributes

The yield components like number of millable cane, cane height, cane girth, number of internodes, and average length of internodes were positively influenced by foliar application of iron, manganese, zinc and hormones like brassinolide and salicylic acid. There was steady correlation exhibited between growth parameters and yield attributes resulting in higher cane yield under micronutrient iron, manganese, zinc and hormonal application of brassinolide and salicylic acid application.

The final output of sugarcane mainly depends on the number of millable canes. The NMC production individually contributed to the yield of cane. The NMC mainly depends upon the tillering capacity and the survival rate of tillers for a given variety. But it is subjected to alteration by various environmental factors.

Application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide recorded 1.65, 2.55 and 2.96 per cent higher NMC than T_{12}, T_7 and T_2 respectively in both the trials (Fig.23).A similar trend was noted in trial II also (Fig.24).This might be due to combined effect of micronutrients and growth regulator brassinolide. Application of ferrous sulphate at 0.5 % twice at 45 and 60 DAP along with recommended dose of N, P and K recorded highest NMC (Srinivas *et al.,* 2001).

The millable cane height had a positive correlation with final yield. Here also, the treatment which received 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide recorded higher cane height of 280 cm followed by T_{12}, T_7, T_5 and T_2 which recorded 260, 255, 251 and 248 cm respectively (Fig.25). A similar trend was seen in trial II also (Fig. 26).Better zinc nutrition would have resulted in increased production of tryptophan and auxin which might have aided in stem elongation (Swarup, 1984) and consequently improved the cane height. Similar improvement in cane height was reported by Jagtap *et al*. (2006).

Millable cane weight is a function of leaf area production, number of internodes, height and girth of individual canes. Application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide recorded higher yield attributes like number of internodes (Fig. 27 & 28), cane height and girth (Fig. 29 & 30) in both the trials, and hence contributed finally to higher millable cane weight (Fig. 31 & 32) in both the trials. With this treatment, millable cane weight was higher by 57 g compared to untreated control (T_1). This is in conformity with the findings of Kumaresan *et al*. (1989), Dwivedi and Singh (1991), and Banger *et al*. (1992).

Though the cane diameter is a varietal character, foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ +0.5 % $ZnSO_4$ + 1 ppm brassinolide influenced the diameter markedly. The above treatment (T_9) recorded thicker cane of 3.07 cm, closely followed by T_{12} (2.99) and T_7 (2.97) while untreated control (T_1) recorded cane thickness of 2.63 cm only .A similar trend was seen in trial II also. The improvement in cane thickness might be due to zinc as confirmed by Dwivedi and Singh (1991). Kumaresan *et al.* (1989) reported that cane thickness was maximum with the soil application of 25 kg $ZnSO_4$ + 0.5 % $ZnSO_4$ foliar spray on 60^{th} day.

The number and average length of internodes were also significantly influenced by various treatments. Among them, foliar feeding of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide registered higher number and average length of internodes .This corroborated the findings of Jagtap *et al*. (2006) who reported increase in number of internodes in sugarcane in non chlorotic healthy sugarcane plants.

5.4 Influence on cane juice quality parameters

The cane juice quality parameters like brix per cent, sucrose per cent, purity coefficient, reducing sugars and commercial cane sugar were significantly influenced by various treatments. Sugarcane responds well to ferrous sulphate application in terms of yield and quality and foliar application is more efficient than soil application (Rakkiyappan and Thangavelu, 2000). Here also the treatment receiving 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide recorded higher juice quality parameters viz. Brix percent (Fig. 33), Pol percent (Fig.34) and CCS per cent

(Fig. 35). Similar trend was seen in the juice quality parameters in trial II also. (Fig. 36, 37 & 38). Srinivas *et al*. (2001) reported that ferrous sulphate @ 0.5 per cent twice at 45 and 60 days after planting along with the recommended dose of NPK fertilizers recorded higher NMC, cane and CCS yield. Yadav *et al*. (1987) and Kapur and Kanwar (1988) observed that ferrous sulphate application appeared to have improved the CCS per cent values. Several workers reported quality improvement through zinc application (Banger *et al*., 1991; Singh *et al*., 2000; Sharma *et al*., 2002; Kadlag *et al*., 2007). Beneficial effects of manganese application on juice quality have been reported by many workers. According to Zende (1968), the application of manganese either through soil or foliar nutrition resulted in better brix per cent, more sucrose and high purity of juice. Bangar *et al.* (1992) reported that foliar application of manganese either alone or in combination with iron and zinc improved the brix and sucrose in cane juice.

5.5 Influence on cane yield and sugar yield

Cane yield depends on the yield components like number of millable cane, cane height, cane girth, number of internodes, and average length of internodes. As previously seen in this chapter all the yield attributing characters were positively influenced by foliar application of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide and hence it had a positive impact on cane yield also. In the present investigation, foliar feeding of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ and 1 ppm Brassinolide increased the cane and sugar yield in both the trials. Higher cane yield of 121 t $ha^{-1}$was recorded in T_9 which was higher by 3.9 and 9.9 per cent over T_{12} and T_7 treatments respectively (Fig. 39). Trial II also followed a similar trend as that of trial I (Fig. 40). The sugar yield also followed a similar trend in both the trials (Fig. 41 & 42). Higher cane yield with the foliar application of ferrous sulphate or in combination with $MnSO_4$ and $ZnSO_4$ might be attributed to the favourable effect on yield attributes and single cane dry weight. De and Singh (1960) observed that increased growth and yield of sugarcane recorded with higher foliar application of ferrous sulphate correlated with higher protein synthesis. Similar correlation was found in the present investigation. Improvement in cane yield by the foliar application of ferrous sulphate has been reported by many workers (De and Singh,

1954; Singh, 1972; Singh and Lallan Singh, 1973; Velu, 1989; Palanivel, 1990; Jayabal *et al*., 1991; Rakkiyappan and Thangavelu, 2000; Srinivas *et al*., 2001).

From the above discussion, it could be inferred that foliar application of iron improved the biometric, growth, physiological / biochemical, yield attributing and juice quality parameters but integration of foliar application of iron with other micronutrients like manganese, zinc as well as growth regulator brassinolide increased the above parameters and productivity of sugarcane variety Co 86032 to a greater extent.

CHAPTER VI

SUMMARY AND CONCLUSION

Sugarcane, which is cultivated commercially in 12 million ha in both tropical and subtropical climates, is one of the world's most important cash crop. It is the major source of sugar and sweeteners and is being cultivated in more than 120 countries around the globe. Brazil, India and Cuba alone account for 2/3rd of the world total cane production. India occupies the second position (13.54 million metric tonnes) in terms of sugar production next to Brazil which produces 26.30 million metric tonnes in 2004 (Anonymous, 2005) and first in terms of sugar production. Micronutrients play important role in the growth and development of sugarcane crop. Though required in small amounts, micronutrients play vital role in most of the physiological activities of the crop by interrupting the level of chlorophyll content in the leaves which ultimately influence the photosynthetic activity of the plant. Micronutrients also play due role in the absorption and translocation of major nutrients like N, P and K. The efficiency of utilization of micronutrients is said to be increased by foliar application of micronutrients. Micronutrients, though required in very small quantities by crops, are equally essential as that of the major and secondary nutrients for the normal growth of the crops.

Among the several micronutrients, iron is regarded as the most important nutrient for sugarcane. Though this element is present in abundance in the soil, yet sugarcane suffers on account of its poor availability. The soils of Tamil Nadu which represents the tropical arid climate are mostly associated with calcium carbonate (Anon, 1973). Presence of high calcium carbonate in the soils induces iron chlorosis in sugarcane as a result of reduction in the availability of soil iron besides considerable decline in the metabolically active iron in the soil and disturbed balance of iron and manganese in the tissue during later stages of growth (Anon, 1984). Iron chlorosis is more frequently noted in sugarcane than the other crops due to high removal of iron (Rakkiyappan, 1987).

Further application of growth regulators has been found to influence the cane yield and improve the juice quality characteristics in sugarcane. Brasssinolide regulates

various physiological responses like cell division, cell elongation, synthesis of nucleic acids and proteins and enhancement of yield in cereals and vegetables. Hence, field experiments were conducted in two locations, the first trial at the Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore and second trial at the farmers field at Puttuvikki village, Selvapuram, Coimbatore during the main season (January planting) of 2007 to study the impact of foliar application of micronutrients viz., iron, manganese, zinc and plant growth regulators brassinolide and salicylic acid on morphological, physiological, biochemical, yield components and quality of sugarcane (cv. Co 86032).

The biometric, physiological / biochemical characteristics were recorded at different time intervals (55, 70, 90,150,210 and 270 DAP) and the yield and juice quality characteristics were recorded at harvest. The results of the experiment are summarized below.

The tillering capacity (7.78%), shoot population (11.17%) and single cane dry weight (9.43 %) were significantly influenced by the treatment T_9 (foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm Brasssinolide) followed by T_7 (foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$).

The growth attributes like LAI, LAD, CGR, RGR, NAR, SLA and SLW were favourably influenced by the foliar application of micronutrients and growth regulators. But a combination of foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide had a pronounced effect on the growth attributes. A highly significant positive correlation was observed between the growth parameters LAI, LAD, CGR, and RGR with cane yield.

The chlorophyll fractions, total chlorophyll content and a/b ratio were also significantly influenced by the treatment T_9 (1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide). A significant positive correlation ($r = 0.407^{*}$) was observed between chlorophyll ‘a’ with cane yield.

The net photosynthetic rate, stomatal conductance and transpiration rate were also influenced by foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide.

Foliar feeding of a combination of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide had significant influence on the Chlorophyll meter readings (SPAD index) which indicates the intensity of chlorophyll in the leaves qualitatively.

Chlorophyll fluorescence values were also influenced by foliar application of micronutrients and growth regulators. But combination of iron with manganese, zinc and growth regulators brassinolide and salicylic (T_9) increased the above parameters significantly.

An increasing trend in the soluble protein was observed in all the treatment but maximum values were registered in T_9 (1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ +1 ppm brassinolide) treatment only. High significant positive correlation ($r = 0.488^{*}$) was observed between soluble protein and cane yield. Photosynthetic rate was also significantly correlated ($r = 0.648^{**}$) with cane yield.

The CEC of roots was also significantly influenced by the various treatments but among them T_9 (1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ +1 ppm brassinolide) recorded higher CEC values.

The antioxidant enzymes viz. catalase and peroxidase were also influenced by the various treatments. Among the various treatments foliar feeding of 1 % $FeSO_4$ had a significant effect on the above enzymes.

The metabolically active fraction of iron which is considered as a correct estimate of active iron status of the plant was greatly influenced by treatment T_2 (1% $FeSO_4$). The combination of micronutrients iron, manganese and zinc along with growth regulator brassinolide (T_9) also equally improved the metabolically active iron status.

Foliar feeding of 1% $FeSO_4$ had a significant effect on the iron manganese balance. The Fe / Mn ratio narrowed down by this treatment which indicates that the plants fed with iron are healthy and devoid of chlorosis. Hence foliar feeding of 1% $FeSO_4$ could alleviate iron chlorosis and restore the normal growth of the plants.

With respect to P/Fe ratio, T_7 (1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$) significantly reduced the ratio which is an indication that application of $FeSO_4$ probably had stimulated the expression of active Fe which is required for the synthesis of chlorophyll and hence retained the healthy nature of the plants.

The yield components like number of millable cane, cane height, cane girth, number of internodes, and average length of internodes were positively influenced by foliar application of iron, manganese, zinc along with growth regulator brassinolide (T_9) and hence resulted in increased cane yield.

The cane juice quality parameters like brix per cent, pol per cent, purity coefficient, reducing sugars and commercial cane sugar were significantly influenced by various treatments. Among the treatments, foliar feeding of 1% $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brassinolide was more effective in enhancing the juice quality parameters.

The combined foliar application of iron with other micronutrients manganese, zinc as well as growth regulator brassinolide improved not only the morphological characters but also the physiological, biochemical, yield attributes and in addition to the juice quality characteristics.

Table 6. Effect of chosen treatments on germination %, tillering capacity (lakh ha^{-1}) and shoot population (lakh ha^{-1}) - (Trial – I)

Treatments	Germination % (40 DAP)	Tillering capacity (lakh ha^{-1}) (100 DAP)	Shoot population (lakh ha^{-1}) (120 DAP)
T_1	79.50	1.30	1.61
T_2	77.42	1.45	1.82
T_3	78.69	1.34	1.62
T_4	82.57	1.38	1.67
T_5	80.02	1.47	1.75
T_6	75.71	1.24	1.77
T_7	77.78	1.37	1.84
T_8	76.53	1.54	1.65
T_9	80.97	1.67	1.88
T_{10}	77.31	1.19	1.79
T_{11}	76.53	1.39	1.70
T_{12}	77.42	1.50	1.86
Mean	77.62	1.40	1.75
SEd	**3.230**	**0.009**	**0.010**
CD (0.05)	**N.S**	**0.019**	**0.021**

Table 7. Effect of chosen treatments on germination %, tillering capacity (lakh/ha) and shoot population (lakh/ha) - (Trial - II)

Treatments	Germination % (40 DAP)	Tillering capacity (lakh/ha) (100 DAP)	Shoot population (lakh/ha) (120 DAP)
T_1	80.70	1.32	1.64
T_2	78.60	1.39	1.85
T_3	79.87	1.36	1.65
T_4	83.80	1.40	1.70
T_5	81.22	1.49	1.78
T_6	76.78	1.26	1.80
T_7	78.95	1.47	1.87
T_8	77.30	1.56	1.68
T_9	82.20	1.69	1.90
T_{10}	78.47	1.21	1.80
T_{11}	77.71	1.41	1.73
T_{12}	78.56	1.52	1.89
Mean	79.51	1.42	1.77
SEd	**3.077**	**0.055**	**0.068**
CD (0.05)	**N.S**	**0.114**	**0.141**

Table 8. Effect of chosen treatments on single cane dry weight (g pl^{-1}) - (Trial- I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	80.57	135.41	185.41	560.00	880.50	1050.00	481.98
T_2	82.53	140.71	193.75	589.50	970.60	1210.00	531.18
T_3	79.45	136.35	187.45	569.65	897.50	1070.00	490.07
T_4	78.65	134.65	188.45	578.65	910.35	1105.00	499.29
T_5	79.25	138.75	192.15	592.35	940.35	1135.00	512.98
T_6	81.25	138.45	190.45	578.45	960.70	1050.00	499.88
T_7	84.65	143.65	195.45	610.89	1010.00	1270.00	552.44
T_8	81.62	137.35	186.75	585.00	901.50	1085.00	496.20
T_9	85.75	154.35	210.45	651.49	1115.00	1410.00	604.51
T_{10}	84.31	144.25	194.75	595.00	950.60	1180.00	524.82
T_{11}	83.75	143.75	197.25	580.00	925.75	1105.00	505.92
T_{12}	80.75	146.35	201.35	625.79	1050.00	1310.00	569.04
Mean	81.88	141.17	193.64	593.06	959.40	1165.00	522.36
SEd	**3.185**	**5.504**	**7.544**	**23.129**	**35.624**	**45.833**	**-**
CD (0.05)	**N.S**	**N.S**	**N.S**	**47.966**	**73.880**	**95.051**	**-**

Table 9. Effect of chosen treatments on single cane dry weight (g .pl^{-1}) - (Trial -II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	85.25	140.75	191.25	570.25	895.25	1100.00	497.13
T_2	87.15	149.25	202.95	601.75	985.25	1225.00	541.89
T_3	87.25	147.25	197.75	581.25	902.75	1125.00	506.88
T_4	89.75	142.75	199.65	587.65	925.75	1215.00	526.76
T_5	87.35	147.65	205.35	607.65	955.35	1235.00	539.73
T_6	89.75	152.35	212.45	592.15	980.25	1265.00	548.66
T_7	93.65	156.75	210.65	625.35	1070.00	1355.00	585.23
T_8	92.15	151.25	198.75	615.25	975.25	1145.00	529.61
T_9	89.75	160.25	230.75	640.35	1100.00	1370.00	598.52
T_{10}	92.15	158.25	221.65	592.35	1040.00	1275.00	563.23
T_{11}	88.75	151.25	207.35	591.65	989.65	1250.00	546.44
T_{12}	96.25	168.75	225.35	680.75	1180.00	1495.00	641.02
Mean	89.93	152.21	208.66	607.20	999.96	1254.58	552.09
SEd	**3.503**	**5.948**	**8.148**	**23.716**	**39.330**	**49.505**	**-**
CD (0.05)	**N.S**	**12.336**	**16.899**	**49.185**	**81.566**	**102.668**	**-**

Table 10. Effect of chosen treatments on leaf area index - (Trial-I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	1.65	1.98	2.25	3.12	3.87	4.71	2.93
T_2	1.81	2.10	2.35	3.33	4.31	5.3	3.20
T_3	1.75	2.06	2.32	3.17	3.93	4.84	3.01
T_4	1.68	1.94	2.29	3.12	3.91	4.87	2.97
T_5	1.69	1.95	2.27	3.09	3.97	4.95	2.99
T_6	1.82	2.14	2.45	3.25	4.15	5.02	3.14
T_7	1.84	2.17	2.5	3.47	4.36	5.26	3.27
T_8	1.71	2.02	2.32	3.12	3.94	4.82	2.99
T_9	1.9	2.35	2.81	3.96	5.02	5.97	3.67
T_{10}	1.85	2.26	2.6	3.35	4.19	5.11	3.23
T_{11}	1.78	2.08	2.4	3.15	3.96	4.91	3.05
T_{12}	1.87	2.30	2.65	3.70	4.64	5.62	3.46
Mean	1.78	2.11	2.43	3.32	4.19	5.12	3.71
SEd	**0.069**	**0.083**	**0.095**	**0.131**	**0.166**	**0.579**	**-**
CD (0.05)	**0.142**	**0.172**	**0.197**	**0.272**	**0.344**	**1.201**	**-**

Table 11. Effect of chosen treatments on leaf area index - (Trial II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	1.78	2.17	2.39	3.32	4.10	4.98	3.12
T_2	1.95	2.25	2.50	3.56	4.58	5.62	3.41
T_3	1.87	2.18	2.48	3.38	4.20	5.12	3.21
T_4	1.80	2.08	2.43	3.36	4.15	5.15	3.16
T_5	1.81	2.10	2.41	3.29	4.25	5.27	3.19
T_6	1.93	2.27	2.62	3.50	4.38	5.32	3.34
T_7	1.96	2.31	2.68	3.74	4.68	5.60	3.50
T_8	1.82	2.20	2.47	3.36	4.24	5.10	3.20
T_9	2.01	2.51	2.98	4.18	5.30	6.32	3.88
T_{10}	1.95	2.38	2.78	3.57	4.45	5.45	3.43
T_{11}	1.89	2.24	2.55	3.38	4.28	5.18	3.25
T_{12}	1.98	2.42	2.82	3.95	4.92	5.98	3.68
Mean	1.90	2.26	2.59	3.55	4.46	5.42	3.36
SEd	**0.074**	**0.088**	**0.101**	**0.140**	**0.174**	**0.213**	**-**
CD (0.05)	**0.154**	**0.183**	**0.209**	**0.291**	**0.362**	**0.442**	**-**

Table 12.Effect of chosen treatments on crop growth rate (g m^{-2} day^{-1}) - (Trial I)

Treatments	55-70 DAP	70-90DAP	90-150 DAP	150-210 DAP	210-270 DAP	Mean
T_1	4.92	5.41	7.67	10.90	9.70	7.72
T_2	6.37	8.08	8.57	14.40	15.20	10.52
T_3	5.30	6.69	8.59	10.71	10.60	8.38
T_4	5.19	6.69	8.88	11.70	12.50	8.99
T_5	5.62	7.02	9.61	12.80	13.60	9.73
T_6	6.23	7.39	9.85	13.20	13.80	10.09
T_7	6.64	8.87	12.70	7.00	18.20	10.68
T_8	5.64	7.07	9.70	12.10	12.80	9.46
T_9	6.92	10.10	14.10	18.90	20.40	14.08
T_{10}	6.48	8.20	10.80	13.70	14.30	10.70
T_{11}	5.75	7.90	9.66	12.20	13.10	9.72
T_{12}	6.16	8.53	11.60	15.40	16.60	11.66
Mean	5.94	7.66	10.14	12.75	14.23	10.15
SEd	**0.234**	**0.305**	**0.409**	**0.519**	**0.579**	**-**
CD (0.05)	**0.486**	**0.634**	**0.849**	**1.077**	**1.200**	**-**

Table 13. Effect of chosen treatments on crop growth rate (g m^{-2} day^{-1}) - (Trial – II)

Treatments	55-70 DAP	70-90DAP	90-150 DAP	150-210 DAP	210-270 DAP	Mean
T_1	5.22	5.74	8.05	10.78	10.23	8.00
T_2	6.79	8.81	11.70	14.96	15.74	11.60
T_3	5.86	7.25	9.16	11.64	16.75	10.13
T_4	5.61	7.31	9.73	12.62	13.10	9.67
T_5	6.06	7.62	10.20	13.43	14.33	10.33
T_6	6.70	8.14	10.40	14.11	14.47	10.76
T_7	6.78	9.29	12.40	16.20	17.32	12.40
T_8	6.25	7.73	10.40	12.70	13.55	10.13
T_9	7.75	10.80	15.20	19.81	20.92	14.90
T_{10}	7.14	9.98	11.50	14.43	14.93	11.60
T_{11}	6.34	7.62	10.30	12.80	13.66	10.14
T_{12}	7.09	9.37	13.50	17.85	18.85	13.33
Mean	6.47	8.31	11.05	14.28	15.32	11.08
SEd	**0.254**	**0.330**	**0.4412**	**0.573**	**0.616**	**-**
CD (0.05)	**0.527**	**0.684**	**0.9149**	**1.189**	**1.277**	**-**

Table 14. Effect of chosen treatments on relative growth rate (mg g^{-1} day^{-1}) - (Trial – I)

Treatments	55- 70 DAP	70-90 DAP	90- 150 DAP	150- 210 DAP	210-270 DAP	Mean
T_1	34.66	15.71	18.42	7.54	2.93	15.85
T_2	35.57	15.99	18.55	8.31	3.67	16.42
T_3	36.01	15.91	18.53	7.58	2.93	16.19
T_4	35.84	16.81	18.7	7.55	3.47	16.47
T_5	37.33	16.28	18.76	7.70	3.14	16.64
T_6	35.53	15.94	18.52	8.46	2.99	16.29
T_7	35.26	15.4	18.99	8.38	3.82	16.37
T_8	34.70	15.36	19.03	7.21	3.09	15.88
T_9	39.64	15.95	18.9	8.63	3.69	17.36
T_{10}	35.80	15.01	18.61	7.79	3.60	16.16
T_{11}	36.02	15.82	17.98	7.80	2.95	16.11
T_{12}	39.19	15.50	18.83	8.96	3.91	17.28
Mean	36.30	15.81	18.65	7.99	3.35	16.42
SEd	**1.413**	**0.613**	**0.724**	**0.315**	**0.132**	**-**
CD (0.05)	**2.930**	**N.S**	**1.502**	**0.653**	**0.273**	**-**

Table 15. Effect of chosen treatments on relative growth rate (mg g^{-1} day^{-1}) - (Trial – II)

Treatments	55- 70 DAP	70-90 DAP	90- 150 DAP	150- 210 DAP	210-270 DAP	Mean
T_1	35.60	16.50	19.34	7.76	3.03	16.45
T_2	36.63	16.47	19.15	8.59	3.78	16.92
T_3	37.10	16.40	19.12	7.84	3.02	16.70
T_4	36.28	15.87	19.56	8.63	3.90	16.85
T_5	40.04	15.97	16.27	8.23	3.45	16.79
T_6	36.30	16.40	19.10	8.72	3.08	16.72
T_7	37.11	16.30	18.52	9.23	4.03	17.04
T_8	35.71	15.82	19.61	7.43	3.12	16.34
T_9	40.80	16.40	19.45	8.89	3.81	17.87
T_{10}	36.84	15.46	19.23	8.03	3.71	16.65
T_{11}	36.90	17.3	19.25	7.70	3.60	16.95
T_{12}	38.45	16.75	19.30	7.95	3.25	17.14
Mean	37.21	16.26	18.96	8.28	3.50	16.84
SEd	**1.451**	**0.634**	**0.736**	**0.323**	**0.135**	**-**
CD (0.05)	**3.006**	**N.S**	**1.5262**	**0.669**	**0.279**	**-**

Table 16. Effect of chosen treatments on net assimilation rate (mg cm^{-2} day^{-1}) - (Trial – I)

Treatments	55- 70 DAP	70- 90 DAP	90- 150 DAP	150-210 DAP	210-270 DAP	Mean
T_1	21.54	25.50	28.50	29.25	22.65	25.49
T_2	32.50	36.25	38.25	37.65	31.65	35.26
T_3	27.75	30.45	31.25	30.18	24.35	28.80
T_4	28.65	31.57	32.75	33.25	28.52	30.95
T_5	30.87	33.25	35.85	36.15	30.57	33.34
T_6	31.47	32.15	34.57	35.75	30.15	32.82
T_7	30.65	36.45	38.70	39.25	34.47	35.90
T_8	30.15	32.57	35.65	34.15	29.25	32.35
T_9	32.50	39.25	41.54	42.15	36.54	38.40
T_{10}	31.45	33.75	36.21	36.37	30.75	33.71
T_{11}	29.77	31.65	34.75	34.25	29.54	31.99
T_{12}	31.75	35.75	39.78	40.78	35.45	36.70
Mean	29.92	33.22	35.65	35.77	30.32	32.98
SEd	**1.171**	**1.307**	**1.402**	**1.412**	**1.204**	**-**
CD (0.05)	**2.427**	**2.710**	**2.908**	**2.928**	**2.497**	**-**

Table 17. Effect of chosen treatments on net assimilation rate - (mg cm^{-2} day^{-1}) (Trial – II)

Treatments	55- 70 DAP	70- 90 DAP	90- 150 DAP	150-210 DAP	210-270 DAP	Mean
T_1	21.68	25.64	28.63	29.40	22.78	25.63
T_2	32.66	36.4	38.39	37.79	31.8	35.41
T_3	27.88	30.58	31.47	31.30	24.52	29.15
T_4	28.79	31.78	32.87	33.38	28.67	31.10
T_5	30.92	33.41	35.98	36.30	30.82	33.49
T_6	31.62	32.31	34.81	35.90	30.33	32.99
T_7	30.8	36.7	38.92	39.53	34.71	36.13
T_8	30.34	32.75	35.82	34.33	29.38	32.52
T_9	32.68	39.43	41.71	42.32	36.7	38.57
T_{10}	31.60	33.92	36.43	36.54	30.92	33.88
T_{11}	29.92	31.90	34.93	34.41	29.7	32.17
T_{12}	31.92	35.91	39.93	40.94	35.71	36.88
Mean	30.07	33.39	35.82	36.01	30.50	33.16
SEd	**1.176**	**1.310**	**1.407**	**1.420**	**1.210**	**-**
CD (0.05)	**2.438**	**2.717**	**2.918**	**2.945**	**2.511**	**-**

Table 18. Effect of chosen treatments on leaf area duration (Days) - (Trial I)

Treatments	55-70 DAP	70-90 DAP	90-150 DAP	150-210 DAP	210-270 DAP	Mean
T_1	27.20	42.30	161.10	209.70	257.40	139.54
T_2	29.30	44.50	170.40	229.20	288.30	152.34
T_3	28.60	43.80	164.70	213.00	263.10	142.64
T_4	27.20	42.30	162.30	210.90	263.40	141.22
T_5	27.30	42.20	160.80	211.80	267.60	141.94
T_6	29.70	45.90	171.00	222.00	275.10	148.74
T_7	30.10	46.70	179.10	234.90	288.60	155.88
T_8	27.90	43.40	163.20	250.20	262.80	149.50
T_9	31.90	51.60	203.10	269.40	363.20	183.84
T_{10}	30.80	48.60	178.50	226.20	279.00	152.62
T_{11}	28.90	44.80	166.50	213.30	266.10	143.92
T_{12}	31.30	49.50	190.50	226.20	307.80	161.06
Mean	29.20	45.47	172.60	226.40	281.87	154.44
SEd	**2.870**	**1.782**	**6.780**	**8.872**	**11.1430**	**-**
CD (0.05)	**5.952**	**3.695**	**14.061**	**18.400**	**23.109**	**-**

Table 19. Effect of chosen treatments on leaf area duration (days) - (Trial – II)

Treatments	55-70 DAP	70-90 DAP	90-150 DAP	150-210 DAP	210-270 DAP	Mean
T_1	28.10	43.60	165.90	216.00	265.20	143.76
T_2	30.20	45.80	175.50	236.10	296.90	156.9
T_3	29.50	45.20	172.90	220.40	270.90	147.78
T_4	28.40	43.60	167.20	217.30	271.30	145.56
T_5	28.80	44.20	165.60	219.50	275.60	146.74
T_6	30.50	47.30	176.20	228.80	283.50	153.26
T_7	31.20	48.50	184.50	242.50	297.30	160.8
T_8	28.70	44.50	168.20	257.80	270.70	153.98
T_9	32.50	53.40	208.30	274.80	374.60	188.72
T_{10}	31.50	50.10	183.50	230.50	285.30	156.18
T_{11}	29.80	46.20	170.50	218.60	272.20	147.46
T_{12}	32.30	50.90	196.20	232.80	317.00	165.84
Mean	29.93	46.58	176.21	232.94	287.59	154.65
SEd	**2.870**	**1.782**	**6.780**	**8.872**	**11.143**	**-**
CD (0.05)	**5.952**	**3.695**	**14.061**	**18.400**	**23.109**	**-**

Table 20. Effect of chosen treatments on specific leaf area (cm^{-2} g) - (Trial I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	125.00	131.50	136.25	140.75	142.50	146.10	137.02
T_2	135.50	140.250	146.50	150.25	153.50	156.70	147.12
T_3	133.10	136.50	140.70	144.60	148.250	150.90	142.34
T_4	126.30	130.25	133.80	136.70	140.50	144.80	135.39
T_5	128.50	135.65	148.20	150.25	155.25	158.50	146.06
T_6	136.80	140.75	144.60	148.25	152.30	158.00	146.78
T_7	139.90	141.25	143.65	145.65	148.80	150.70	144.99
T_8	128.10	133.25	137.50	140.60	143.25	150.20	138.82
T_9	143.40	150.50	156.80	162.50	168.25	172.80	159.04
T_{10}	140.20	145.35	151.35	155.10	161.75	166.20	153.33
T_{11}	133.30	139.75	141.10	143.25	150.15	154.70	143.71
T_{12}	142.20	146.25	150.25	157.25	162.70	169.70	154.73
Mean	134.36	139.27	144.23	147.93	152.27	156.61	145.78
SEd	**5.248**	**5.434**	**5.623**	**5.769**	**5.940**	**6.084**	**-**
CD (0.05)	**10.883**	**11.269**	**11.661**	**11.964**	**12.318**	**12.617**	**-**

Table 21. Effect of chosen treatments on specific leaf area (cm^{-2} g) - (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	126.25	132.80	137.60	142.20	143.90	147.50	138.38
T_2	136.8	141.60	147.90	151.80	155.00	158.30	148.57
T_3	134.4	137.80	140.10	146.00	149.70	152.40	143.40
T_4	127.6	131.60	135.10	138.10	141.90	146.20	136.75
T_5	129.8	137.00	149.70	151.80	156.80	160.10	147.53
T_6	138.2	142.20	146.00	149.70	153.80	159.60	148.25
T_7	141.6	146.80	152.90	156.70	162.90	167.90	154.80
T_8	129.4	134.60	138.90	142.00	144.70	151.70	140.22
T_9	144.8	152.00	158.40	164.10	169.90	174.50	160.62
T_{10}	141.3	142.60	145.10	147.10	150.30	152.20	146.43
T_{11}	134.6	141.20	142.50	151.70	152.80	156.10	146.48
T_{12}	143.6	147.70	151.80	158.80	164.30	171.40	156.27
Mean	135.70	140.66	145.50	150.00	153.83	158.16	147.31
SEd	**5.298**	**5.491**	**5.6820**	**5.863**	**6.023**	**6.200**	**-**
CD (0.05)	**10.988**	**11.389**	**11.784**	**12.160**	**12.490**	**12.858**	**-**

Table 22.Effect of chosen treatments on specific leaf weight (mg cm^{-2}) - (Trial I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	8.68	8.50	8.25	7.77	7.61	7.42	8.04
T_2	8.50	8.04	7.67	7.22	7.06	7.05	7.59
T_3	8.35	8.23	7.98	7.50	7.31	7.18	7.76
T_4	8.90	7.58	7.19	6.68	6.44	6.27	7.18
T_5	8.44	8.28	7.58	7.22	6.98	6.84	7.56
T_6	8.58	8.02	7.77	7.32	7.13	6.86	7.61
T_7	8.72	7.77	7.48	6.90	6.66	6.39	7.32
T_8	8.77	8.00	7.83	7.45	7.29	7.19	7.76
T_9	8.60	8.57	8.40	7.93	7.72	7.49	8.12
T_{10}	8.70	7.81	7.43	6.99	6.72	6.52	7.36
T_{11}	8.36	8.07	7.97	7.57	7.22	7.01	7.70
T_{12}	8.46	8.40	8.18	7.71	7.57	7.22	7.92
Mean	8.60	8.08	7.78	7.32	7.10	6.93	7.64
SEd	**0.334**	**0.312**	**0.301**	**0.284**	**0.276**	**0.268**	**-**
CD (0.05)	**N.S**	**0.648**	**0.625**	**0.590**	**0.573**	**0.555**	**-**

Table 23. Effect of chosen treatments on specific leaf weight (mg cm^{-2}) - (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	8.78	8.47	8.37	7.95	7.58	7.36	8.09
T_2	8.92	8.44	8.05	7.58	7.41	7.40	7.97
T_3	8.77	8.64	8.37	7.88	7.68	7.54	8.15
T_4	9.35	7.95	7.55	7.01	6.76	6.58	7.53
T_5	8.86	8.69	7.96	7.58	7.33	7.18	7.93
T_6	8.67	8.42	8.16	7.69	7.49	7.20	7.94
T_7	8.88	8.82	8.58	8.1	7.95	7.58	8.32
T_8	9.14	8.16	7.58	7.25	6.99	6.70	7.64
T_9	9.03	8.99	8.82	8.32	8.11	7.86	8.52
T_{10}	9.13	8.20	7.8	7.34	7.06	6.85	7.73
T_{11}	8.86	8.40	8.22	7.82	7.65	7.55	8.08
T_{12}	9.11	8.93	8.66	8.16	7.99	7.79	8.44
Mean	8.94	8.47	8.13	7.68	7.46	7.25	7.99
SEd	**0.346**	**0.3312**	**0.320**	**0.303**	**0.294**	**0.286**	**-**
CD (0.05)	**N.S**	**N.S**	**0.664**	**0.627**	**0.610**	**0.594**	**-**

Table 24. Effect of chosen treatments on chlorophyll 'a 'content (mg g^{-1}) - (Trial-I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.653	0.941	1.200	1.361	1.622	1.372	1.192
T_2	0.700	0.997	1.254	1.437	1.762	1.497	1.275
T_3	0.737	1.029	1.029	1.430	1.715	1.452	1.232
T_4	0.705	1.002	1.002	1.443	1.775	1.419	1.224
T_5	0.728	0.103	1.031	1.465	1.698	1.552	1.096
T_6	0.725	1.045	1.045	1.477	1.764	1.625	1.280
T_7	0.715	1.033	1.033	1.430	1.659	1.536	1.234
T_8	0.667	0.997	0.997	1.356	1.688	1.623	1.221
T_9	0.742	1.039	1.039	1.497	1.826	1.602	1.291
T_{10}	0.715	1.032	1.032	1.419	1.623	1.501	1.220
T_{11}	0.687	0.949	0.949	1.337	1.552	1.384	1.143
T_{12}	0.740	1.036	1.036	1.151	1.845	1.646	1.076
Mean	0.710	0.934	1.054	1.400	1.711	1.517	1.207
SEd	**0.028**	**0.039**	**0.041**	**0.053**	**0.067**	**0.060**	**-**
CD (0.05)	**N.S**	**0.080**	**0.086**	**0.111**	**0.138**	**0.124**	**-**

Table 25. Effect of chosen treatments on chlorophyll 'a' content (mg g^{-1}) – (Trial II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.670	0.975	1.210	1.390	1.752	1.450	1.241
T_2	0.750	1.110	1.310	1.520	1.792	1.540	1.337
T_3	0.850	1.135	1.350	1.570	1.870	1.542	1.386
T_4	0.760	1.132	1.317	1.540	1.825	1.468	1.340
T_5	0.739	1.131	1.325	1.562	1.875	1.652	1.381
T_6	0.750	1.125	1.410	1.625	1.815	1.585	1.385
T_7	0.780	1.215	1.345	1.439	1.725	1.625	1.355
T_8	0.710	0.980	1.321	1.432	1.715	1.615	1.296
T_9	0.789	1.175	1.415	1.570	1.870	1.625	1.407
T_{10}	0.725	1.115	1.279	1.527	1.735	1.545	1.321
T_{11}	0.695	0.987	1.245	1.385	1.595	1.415	1.220
T_{12}	0.770	1.145	1.350	1.540	1.862	1.670	1.390
Mean	0.749	1.098	1.321	1.505	1.779	1.551	1.334
SEd	**0.029**	**0.043**	**0.052**	**0.060**	**0.069**	**0.061**	**-**
CD (0.05)	**0.062**	**0.090**	**0.108**	**0.123**	**0.143**	**0.127**	**-**

Table 26. Effect of chosen treatments on chlorophyll 'b'content (mg g^{-1}) - (Trial –I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.264	0.373	0.463	0.513	0.608	0.505	0.454
T_2	0.278	0.387	0.471	0.523	0.648	0.534	0.474
T_3	0.266	0.391	0.467	0.513	0.617	0.510	0.461
T_4	0.290	0.402	0.473	0.551	0.680	0.535	0.489
T_5	0.291	0.393	0.452	0.514	0.587	0.546	0.464
T_6	0.290	0.411	0.491	0.537	0.661	0.602	0.499
T_7	0.278	0.391	0.443	0.520	0.582	0.558	0.462
T_8	0.271	0.382	0.461	0.490	0.615	0.575	0.466
T_9	0.283	0.401	0.493	0.541	0.648	0.579	0.491
T_{10}	0.278	0.394	0.454	0.503	0.570	0.539	0.456
T_{11}	0.288	0.386	0.462	0.505	0.575	0.529	0.458
T_{12}	0.277	0.377	0.472	0.513	0.605	0.564	0.468
Mean	0.280	0.391	0.467	0.519	0.616	0.548	0.470
SEd	**0.011**	**0.016**	**0.019**	**0.020**	**0.024**	**0.022**	**-**
CD (0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**0.049**	**0.045**	**-**

Table 27. Effect of chosen treatments on chlorophyll 'b'content (mg g^{-1}) - (Trial-II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.253	0.362	0.440	0.500	0.600	0.492	0.441
T_2	0.285	0.413	0.470	0.539	0.618	0.519	0.474
T_3	0.298	0.420	0.489	0.547	0.654	0.523	0.489
T_4	0.295	0.434	0.490	0.560	0.664	0.524	0.495
T_5	0.282	0.427	0.467	0.539	0.644	0.560	0.487
T_6	0.272	0.392	0.488	0.543	0.576	0.516	0.465
T_7	0.289	0.442	0.474	0.501	0.587	0.562	0.476
T_8	0.269	0.370	0.478	0.500	0.617	0.559	0.466
T_9	0.300	0.429	0.502	0.548	0.677	0.599	0.509
T_{10}	0.270	0.407	0.450	0.528	0.600	0.538	0.466
T_{11}	0.279	0.384	0.470	0.511	0.572	0.526	0.457
T_{12}	0.296	0.445	0.509	0.547	0.647	0.568	0.502
Mean	0.282	0.410	0.477	0.530	0.621	0.541	0.477
SEd	**0.011**	**0.016**	**0.018**	**0.021**	**0.025**	**0.021**	**-**
CD (0.05)	**0.023**	**0.034**	**0.038**	**N.S**	**0.052**	**0.044**	**-**

Table 28. Effect of chosen treatments on total chlorophyll content (mg g^{-1}) - (Trial – 1)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.917	1.314	1.663	1.874	2.230	1.877	1.646
T_2	1.017	1.413	1.508	0.664	2.450	2.210	1.544
T_3	1.003	1.420	1.717	1.943	2.332	1.962	1.730
T_4	0.995	1.404	1.690	1.994	2.455	1.954	1.749
T_5	1.019	1.424	1.690	1.979	2.285	2.098	1.749
T_6	0.978	1.384	1.725	1.960	2.410	2.031	1.748
T_7	0.993	1.424	1.476	1.950	2.241	2.094	1.696
T_8	0.938	1.359	1.692	1.846	2.303	2.198	1.723
T_9	1.015	1.456	1.779	2.014	2.425	2.227	1.819
T_{10}	0.993	1.426	1.702	1.922	2.193	2.040	1.713
T_{11}	0.975	1.335	1.658	1.842	2.127	1.913	1.642
T_{12}	1.025	1.440	1.532	2.038	2.474	2.181	1.782
Mean	0.989	1.400	1.653	1.836	2.327	2.065	1.712
SEd	**0.039**	**0.199**	**0.067**	**0.076**	**0.090**	**0.081**	**-**
CD (0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**0.187**	**0.167**	**-**

Table 29. Effect of chosen treatments on total chlorophyll content (mg g^{-1}) - (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.923	1.337	1.650	1.891	2.352	1.942	1.683
T_2	1.035	1.523	1.780	2.058	2.410	2.059	1.811
T_3	1.148	1.555	1.839	2.117	2.524	2.065	1.875
T_4	1.055	1.566	1.807	2.100	2.489	1.992	1.835
T_5	1.021	1.558	1.792	2.101	2.519	2.212	1.867
T_6	1.022	1.517	1.898	2.168	2.391	2.101	1.850
T_7	1.069	1.657	1.819	1.940	2.312	2.224	1.837
T_8	0.979	1.350	1.799	1.932	2.332	2.174	1.761
T_9	1.089	1.604	1.917	2.118	2.547	2.224	1.917
T_{10}	0.995	1.522	1.729	2.055	2.127	2.183	1.769
T_{11}	0.974	1.371	1.715	1.896	1.957	1.941	1.642
T_{12}	1.066	1.590	1.859	2.087	2.509	2.238	1.892
Mean	1.031	1.513	1.800	2.039	2.372	2.113	1.811
SEd	**0.040**	**0.059**	**0.070**	**0.080**	**0.092**	**0.083**	**-**
CD (0.05)	**0.083**	**0.123**	**0.145**	**0.165**	**0.191**	**0.172**	**-**

Table 30. Effect of chosen treatments on chlorophyll a /b ratio - (Trial – I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	2.47	2.52	2.59	2.65	2.67	2.72	2.60
T_2	2.52	2.58	2.66	2.75	2.72	2.80	2.67
T_3	2.77	2.63	2.68	2.79	2.78	2.85	2.75
T_4	2.43	2.49	2.57	2.62	2.61	2.65	2.56
T_5	2.50	2.62	2.74	2.85	2.89	2.84	2.74
T_6	2.49	2.54	2.62	2.75	2.67	2.70	2.63
T_7	2.57	2.64	2.76	2.75	2.85	2.75	2.72
T_8	2.46	2.56	2.67	2.77	2.79	2.82	2.68
T_9	2.67	2.75	2.84	2.95	3.05	2.92	2.86
T_{10}	2.57	2.62	2.75	2.82	2.85	2.78	2.73
T_{11}	2.38	2.46	2.59	2.65	2.70	2.61	2.57
T_{12}	2.62	2.59	2.69	2.77	2.82	2.75	2.71
Mean	2.54	2.58	2.68	2.76	2.78	2.77	2.69
SEd	**0.104**	**0.803**	**0.110**	**0.117**	**0.803**	**0.076**	**-**
CD (0.05)	**0.216**	**1.091**	**N.S**	**N.S**	**0.172**	**0.158**	**-**

Table 31. Effect of chosen treatments on Chlorophyll a /b ratio - (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	2.65	2.69	2.75	2.78	2.92	2.95	2.79
T_2	2.63	2.69	2.79	2.82	2.90	2.97	2.80
T_3	2.85	2.70	2.76	2.87	2.86	2.95	2.83
T_4	2.57	2.61	2.69	2.75	2.75	2.80	2.70
T_5	2.62	2.65	2.84	2.90	2.91	2.95	2.81
T_6	2.57	2.67	2.69	2.81	2.75	2.79	2.71
T_7	2.69	2.75	2.84	2.87	2.94	2.89	2.83
T_8	2.64	2.65	2.76	2.86	2.78	2.89	2.76
T_9	2.76	2.87	2.89	2.99	3.15	3.07	2.96
T_{10}	2.69	2.74	2.84	2.89	2.89	2.87	2.82
T_{11}	2.49	2.57	2.65	2.71	2.79	2.69	2.65
T_{12}	2.67	2.64	2.78	2.87	2.89	2.86	2.79
Mean	2.65	2.69	2.77	2.84	2.88	2.89	2.79
SEd	**0.102**	**0.103**	**0.107**	**0.110**	**0.112**	**0.111**	**-**
CD (0.05)	**0.210**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**-**

Table 32. Effect of chosen treatments on chlorophyll fluorescence - (Fv/Fm) (Trial –I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.710	0.750	0.795	0.817	0.862	0.812	0.791
T_2	0.720	0.795	0.820	0.835	0.869	0.825	0.811
T_3	0.715	0.725	0.780	0.810	0.840	0.827	0.783
T_4	0.720	0.742	0.765	0.798	0.825	0.752	0.767
T_5	0.727	0.810	0.847	0.868	0.890	0.840	0.830
T_6	0.730	0.750	0.780	0.810	0.840	0.827	0.790
T_7	0.741	0.755	0.865	0.899	0.910	0.881	0.842
T_8	0.725	0.782	0.810	0.840	0.855	0.780	0.799
T_9	0.760	0.820	0.910	0.925	0.940	0.920	0.879
T_{10}	0.750	0.780	0.815	0.850	0.897	0.850	0.824
T_{11}	0.710	0.745	0.767	0.795	0.825	0.760	0.767
T_{12}	0.740	0.775	0.885	0.920	0.927	0.825	0.845
Mean	0.729	0.769	0.820	0.847	0.873	0.825	0.811
SEd	**0.030**	**0.029**	**0.033**	**0.033**	**0.034**	**0.033**	**-**
CD (0.05)	**N.S**	**N.S**	**0.068**	**0.068**	**0.072**	**0.069**	**-**

Table 33. Effect of chosen treatments on chlorophyll fluorescence (Fv/Fm) - (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.745	0.785	0.810	0.842	0.806	0.782	0.704
T_2	0.775	0.800	0.825	0.852	0.810	0.796	0.714
T_3	0.712	0.765	0.790	0.820	0.802	0.766	0.704
T_4	0.724	0.750	0.782	0.810	0.742	0.751	0.695
T_5	0.790	0.835	0.853	0.875	0.825	0.815	0.710
T_6	0.739	0.765	0.794	0.824	0.805	0.774	0.716
T_7	0.740	0.850	0.887	0.900	0.860	0.827	0.724
T_8	0.765	0.790	0.823	0.840	0.765	0.781	0.700
T_9	0.805	0.890	0.911	0.927	0.905	0.864	0.747
T_{10}	0.765	0.795	0.835	0.885	0.830	0.808	0.738
T_{11}	0.730	0.752	0.780	0.800	0.745	0.750	0.695
T_{12}	0.760	0.870	0.905	0.920	0.876	0.843	0.727
Mean	0.754	0.804	0.833	0.858	0.814	0.796	0.715
SEd	**0.030**	**0.032**	**0.032**	**0.035**	**0.036**	**0.034**	**-**
CD (0.05)	**N.S**	**N.S**	**0.067**	**0.072**	**0.074**	**0.071**	**-**

Table 34. Effect of chosen treatments on SPAD index - (Trial – I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	32.02	32.84	34.26	36.04	37.67	33.81	34.44
T_2	32.40	32.67	34.08	35.57	37.43	34.79	34.49
T_3	32.93	34.38	34.65	35.55	36.79	35.18	34.91
T_4	31.35	32.16	32.99	34.12	35.01	31.91	32.92
T_5	31.71	33.07	34.78	36.90	37.87	34.53	34.81
T_6	32.77	33.90	35.07	35.68	36.62	35.01	34.84
T_7	34.82	38.43	40.12	42.97	43.74	37.86	39.66
T_8	34.35	35.04	37.09	37.74	38.97	33.62	36.14
T_9	37.44	41.71	43.27	43.97	45.04	44.40	42.64
T_{10}	33.26	34.69	36.51	38.75	41.42	35.94	36.76
T_{11}	31.70	33.06	34.77	36.31	36.93	32.06	34.14
T_{12}	36.74	39.54	41.78	42.51	44.45	41.28	41.05
Mean	33.46	35.12	36.61	38.01	39.33	35.87	36.40
SEd	**1.309**	**1.382**	**1.441**	**1.496**	**1.545**	**1.431**	**-**
CD (0.05)	**2.713**	**2.865**	**2.988**	**3.103**	**3.203**	**2.967**	**-**

Table 35. Effect of chosen treatments on SPAD index - (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	33.72	34.15	35.17	37.15	38.25	34.15	35.43
T_2	33.50	33.15	34.90	35.97	38.20	35.35	35.18
T_3	33.67	35.20	35.20	35.10	36.95	35.79	35.32
T_4	31.95	32.78	33.75	35.10	35.65	32.45	33.61
T_5	32.21	33.75	35.10	37.20	38.15	34.92	35.22
T_6	33.45	34.65	35.82	36.20	37.10	36.20	35.57
T_7	35.12	39.57	41.32	43.65	44.10	38.75	40.42
T_8	35.45	36.10	38.50	38.25	39.25	34.25	36.97
T_9	38.27	42.65	44.17	44.39	46.75	45.30	43.59
T_{10}	34.15	35.72	37.27	39.51	42.41	37.20	37.71
T_{11}	32.75	34.09	35.65	37.45	37.85	33.10	35.15
T_{12}	37.57	40.45	42.58	43.52	45.54	42.38	42.01
Mean	34.32	36.02	37.45	38.62	40.02	36.65	37.18
SEd	**1.34**	**1.42**	**1.48**	**1.51**	**1.57**	**1.45**	**-**
CD (0.05)	**2.79**	**2.94**	**3.06**	**3.14**	**3.26**	**3.00**	**-**

Table 36. Effect of chosen treatments on soluble protein content (mg g^{-1}) - (Trial -I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	8.06	9.29	9.69	11.01	12.78	13.55	10.73
T_2	11.18	13.43	14.79	17.20	18.75	19.20	15.76
T_3	11.10	13.10	14.00	16.50	18.20	19.50	15.40
T_4	11.64	12.87	13.55	17.20	18.95	19.95	15.69
T_5	11.65	12.95	13.90	16.85	18.65	19.80	15.63
T_6	11.38	13.00	14.40	17.00	18.90	20.00	15.78
T_7	11.24	13.50	15.00	16.20	19.00	20.35	15.88
T_8	11.50	13.05	13.50	15.90	18.40	19.85	15.37
T_9	11.75	13.95	15.15	17.50	19.20	22.50	16.68
T_{10}	11.62	12.95	13.40	16.00	18.00	20.52	15.41
T_{11}	11.67	13.22	12.95	15.00	17.70	20.00	15.09
T_{12}	11.75	13.40	15.65	17.80	19.93	21.10	16.61
Mean	11.21	12.89	13.83	16.18	18.21	19.69	15.34
SEd	**0.451**	**0.522**	**0.562**	**0.652**	**0.797**	**0.735**	**-**
CD (0.05)	**0.936**	**1.082**	**1.166**	**1.353**	**1.653**	**1.525**	**-**

Table 37. Effect of chosen treatments on soluble protein content (mg g^{-1}) - (Trial-II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	9.43	10.66	11.06	12.66	15.20	14.43	12.24
T_2	12.55	14.80	16.16	18.85	20.85	20.40	17.27
T_3	12.47	14.47	15.37	18.15	21.15	19.85	16.91
T_4	13.01	14.24	14.92	18.85	21.60	20.60	17.20
T_5	13.02	14.32	15.27	18.50	21.45	20.30	17.14
T_6	12.75	14.37	15.77	18.65	21.65	20.55	17.29
T_7	12.61	14.87	16.37	17.85	22.00	20.65	17.39
T_8	12.87	14.42	14.87	17.55	21.50	20.05	16.88
T_9	13.12	15.32	16.52	19.15	24.15	20.85	18.19
T_{10}	12.99	14.32	14.77	17.65	22.17	19.65	16.93
T_{11}	13.04	14.59	14.32	16.65	21.65	19.35	16.60
T_{12}	13.12	14.77	17.02	19.45	22.75	21.58	18.12
Mean	12.58	14.26	15.20	17.83	21.34	19.86	16.85
SEd	**0.490**	**0.557**	**0.598**	**0.696**	**0.837**	**0.776**	**-**
CD (0.05)	**1.016**	**1.156**	**1.241**	**1.444**	**1.736**	**1.609**	**-**

Table 38. Effect of chosen treatments on net photosynthetic rate (μ mol m^{-2} s^{-1}) - (Trial -I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	12.07	12.77	13.45	14.4	14.97	14.32	13.66
T_2	12.24	13.28	13.71	14.66	15.15	14.4	13.91
T_3	12.07	12.20	13.11	14.04	14.57	14.25	13.37
T_4	11.91	12.41	12.85	13.9	14.4	13.91	13.23
T_5	12.17	13.54	14.31	15.16	15.55	14.66	14.23
T_6	12.27	12.67	13.11	14.11	14.65	14.31	13.52
T_7	12.41	12.69	14.57	15.77	16	15.28	14.45
T_8	12.00	13.11	13.54	14.63	14.93	13.6	13.64
T_9	12.80	13.80	15.25	16.19	16.48	16.08	15.10
T_{10}	12.65	13.11	13.62	14.84	15.73	14.75	14.12
T_{11}	11.91	12.51	12.89	13.86	14.22	13.24	13.11
T_{12}	12.46	13.02	14.91	16.35	15.25	15.57	14.59
Mean	12.25	12.93	13.78	14.83	15.16	14.53	13.91
SEd	**0.475**	**0.501**	**0.539**	**0.580**	**0.589**	**0.568**	**-**
CD (0.05)	**N.S**	**N.S**	**1.119**	**1.203**	**1.222**	**1.178**	**-**

Table 39. Effect of chosen treatments on net photosynthetic rate (µ mol m^{-2} s^{-1}) - (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	12.17	12.86	13.63	14.53	15.33	14.44	13.83
T_2	12.34	13.63	14.06	15.91	15.45	14.67	14.34
T_3	12.25	12.43	13.37	14.40	14.93	14.70	13.68
T_4	12.34	12.72	13.11	14.19	14.67	13.37	13.40
T_5	12.46	13.89	14.52	15.43	15.82	14.93	14.51
T_6	12.51	12.86	13.37	14.40	14.93	14.70	13.80
T_7	12.70	12.94	14.83	16.18	16.18	15.66	14.75
T_8	12.43	13.41	13.89	14.93	15.20	13.87	13.96
T_9	13.03	14.06	15.60	16.44	16.71	16.35	15.37
T_{10}	12.86	12.77	13.97	15.95	15.95	15.11	14.44
T_{11}	12.17	13.29	13.15	14.67	14.27	13.51	13.51
T_{12}	12.69	13.19	15.17	16.33	16.48	14.66	14.75
Mean	12.50	13.17	14.06	15.28	15.49	14.66	14.19
SEd	**0.679**	**0.714**	**0.769**	**0.797**	**0.817**	**0.772**	**-**
CD (0.05)	**1.409**	**1.481**	**1.594**	**1.652**	**1.693**	**1.601**	**-**

Table 40. Effect of chosen treatments on stomatal conductance (m mol m^{-2} s^{-1}) - (Trial – I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	187.60	198.40	209.00	223.80	232.70	222.50	212.33
T_2	190.20	206.30	213.00	227.80	235.40	223.80	216.08
T_3	187.50	189.50	203.70	218.20	226.40	221.50	207.80
T_4	185.10	192.80	194.30	216.00	223.80	216.20	204.70
T_5	189.70	210.41	222.37	235.60	241.70	227.80	221.26
T_6	190.67	196.89	203.72	219.30	227.80	222.40	210.13
T_7	192.85	197.20	226.40	245.10	248.60	237.50	224.61
T_8	186.50	203.70	210.40	229.40	232.00	211.30	212.22
T_9	198.90	214.50	236.90	251.60	256.10	249.90	234.65
T_{10}	196.60	203.70	211.70	230.60	244.40	229.20	219.37
T_{11}	185.10	194.40	200.30	215.40	220.90	205.80	203.65
T_{12}	193.60	202.30	231.70	254.10	236.90	241.90	226.75
Mean	190.36	200.84	213.62	230.58	235.56	225.82	216.13
SEd	**7.117**	**7.778**	**8.351**	**9.012**	**9.156**	**8.824**	**-**
CD (0.05)	**N.S**	**N.S**	**17.320**	**18.690**	**18.989**	**18.301**	**-**

Table 41. Effect of chosen treatments on stomatal conductance (m mol m^{-2} s^{-1}) - (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	189.10	199.80	211.80	225.80	238.20	224.40	214.85
T_2	191.80	211.80	218.50	247.20	240.10	227.90	222.88
T_3	190.40	193.40	207.80	223.80	232.02	228.40	212.64
T_4	191.80	197.70	203.70	220.50	227.90	207.80	208.23
T_5	193.60	215.90	225.60	239.80	245.80	232.00	225.45
T_6	194.40	199.80	207.80	223.80	232.00	228.40	214.37
T_7	197.40	201.10	230.50	251.40	251.40	243.40	229.20
T_8	193.20	208.40	215.90	232.00	236.20	215.50	216.87
T_9	202.50	218.50	242.40	255.50	259.70	254.10	238.78
T_{10}	199.80	198.50	217.10	247.90	247.90	234.80	224.33
T_{11}	189.10	206.50	204.40	227.90	227.90	209.90	210.95
T_{12}	197.20	204.90	235.70	253.80	256.10	227.80	229.25
Mean	194.19	204.69	218.43	237.45	241.27	227.87	220.65
SEd	**7.540**	**7.929**	**8.527**	**9.248**	**9.398**	**8.893**	**-**
CD (0.05)	**N.S**	**N.S**	**17.684**	**19.180**	**19.490**	**18.444**	**-**

Table 42. Effect of chosen treatments on transpiration rate (m mol m^{-2} s^{-1}) - (Trial – I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.402	0.431	0.451	0.485	0.510	0.491	0.462
T_2	0.410	0.462	0.467	0.495	0.512	0.485	0.472
T_3	0.419	0.415	0.445	0.475	0.495	0.482	0.455
T_4	0.399	0.423	0.439	0.478	0.497	0.485	0.454
T_5	0.417	0.465	0.482	0.520	0.530	0.492	0.484
T_6	0.412	0.435	0.445	0.481	0.497	0.485	0.459
T_7	0.421	0.429	0.495	0.535	0.548	0.525	0.492
T_8	0.399	0.436	0.451	0.497	0.510	0.465	0.460
T_9	0.425	0.439	0.510	0.545	0.515	0.525	0.493
T_{10}	0.427	0.440	0.459	0.510	0.547	0.510	0.482
T_{11}	0.399	0.427	0.453	0.499	0.540	0.495	0.469
T_{12}	0.437	0.471	0.512	0.545	0.565	0.545	0.513
Mean	0.414	0.439	0.467	0.505	0.522	0.499	0.475
SEd	**0.016**	**0.017**	**0.019**	**0.020**	**0.022**	**0.020**	**-**
CD (0.05)	**N.S**	**N.S**	**0.040**	**0.042**	**0.045**	**0.041**	**-**

Table 43. Effect of chosen treatments on transpiration rate (m mol m^{-2} s^{-1}) - (Trial II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.415	0.438	0.463	0.492	0.521	0.488	0.470
T_2	0.419	0.462	0.477	0.527	0.529	0.492	0.484
T_3	0.416	0.423	0.454	0.488	0.506	0.496	0.464
T_4	0.420	0.431	0.445	0.483	0.497	0.457	0.456
T_5	0.423	0.442	0.478	0.521	0.537	0.505	0.484
T_6	0.421	0.437	0.453	0.490	0.508	0.496	0.468
T_7	0.429	0.438	0.501	0.536	0.547	0.530	0.497
T_8	0.422	0.445	0.471	0.505	0.517	0.473	0.472
T_9	0.441	0.479	0.528	0.558	0.569	0.558	0.522
T_{10}	0.430	0.436	0.473	0.538	0.547	0.515	0.490
T_{11}	0.414	0.440	0.450	0.497	0.507	0.458	0.461
T_{12}	0.432	0.448	0.513	0.549	0.553	0.496	0.499
Mean	0.424	0.443	0.476	0.515	0.528	0.497	0.480
SEd	**0.016**	**0.016**	**0.019**	**0.020**	**0.020**	**0.020**	**-**
CD (0.05)	**N.S**	**N.S**	**0.039**	**0.041**	**0.042**	**0.042**	**-**

Table 44.Effect of chosen treatments on cation exchange capacity (meq 100 g^{-1}) - (Trial - I)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	14.24	15.35	16.60	15.40
T_2	18.10	18.95	20.65	19.23
T_3	16.52	17.45	17.60	17.19
T_4	16.75	17.45	17.80	17.33
T_5	17.98	18.78	19.25	18.67
T_6	18.01	18.86	20.61	19.16
T_7	18.84	19.42	20.74	19.67
T_8	17.01	17.70	18.25	17.65
T_9	20.50	19.97	21.96	20.81
T_{10}	14.50	16.78	18.45	16.58
T_{11}	14.46	15.78	16.43	15.56
T_{12}	19.07	19.76	21.63	20.15
Mean	16.99	17.86	18.94	17.93
SEd	**0.681**	**0.709**	**0.757**	**-**
CD (0.05)	**1.412**	**1.470**	**1.567**	**-**

Table 45. Effect of chosen treatments on cation exchange capacity (meq 100 g^{-1}) (Trial – II) -

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	15.05	16.12	17.43	16.20
T_2	19.01	19.88	21.65	20.18
T_3	17.35	18.30	18.45	18.03
T_4	17.55	18.33	18.68	18.19
T_5	18.85	19.70	20.21	19.59
T_6	18.90	19.80	21.65	20.12
T_7	19.78	20.39	21.77	20.65
T_8	17.86	18.59	19.16	18.54
T_9	20.02	20.75	22.72	21.16
T_{10}	15.23	17.62	19.37	17.41
T_{11}	15.10	17.12	17.25	16.49
T_{12}	15.18	16.54	23.06	18.26
Mean	17.49	18.60	20.12	18.73
SEd	**0.685**	**0.727**	**0.794**	**-**
CD (0.05)	**1.420**	**1.508**	**1.646**	**-**

Table 46. Effect of chosen treatments on catalase activity ($\mu g H_2O_2\ g^{-1}\ min^{-1}$) - (Trial – I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	1.08	1.16	1.19	1.23	1.20	1.15	1.17
T_2	11.34	11.65	12.50	13.90	14.30	14.12	12.97
T_3	2.06	2.20	2.32	2.45	2.10	2.04	2.20
T_4	2.92	2.90	3.00	3.15	3.00	2.85	2.97
T_5	7.30	7.45	7.75	7.95	7.10	6.98	7.42
T_6	7.22	7.30	7.40	7.55	6.85	6.62	7.16
T_7	2.32	2.40	2.55	2.75	2.45	2.32	2.47
T_8	2.15	2.25	2.45	2.60	2.35	2.20	2.33
T_9	6.50	6.70	6.90	7.15	7.05	6.87	6.86
T_{10}	6.10	6.20	6.42	6.65	6.40	6.29	6.34
T_{11}	2.95	3.00	3.15	3.35	3.11	3.01	3.10
T_{12}	6.35	6.54	6.75	6.90	6.72	6.56	6.64
Mean	4.86	4.98	5.20	5.47	5.22	5.08	5.13
SEd	**0.225**	**0.229**	**0.240**	**0.254**	**0.249**	**0.378**	**-**
CD (0.05)	**0.475**	**0.475**	**0.480**	**0.270**	**0.517**	**0.783**	**-**

Table 47. Effect of chosen treatments on catalase content ($\mu g H_2O_2\ g^{-1}\ min^{-1}$) (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	1.25	1.33	1.38	1.46	1.37	1.21	1.33
T_2	11.52	11.79	12.68	14.48	13.67	13.18	12.89
T_3	2.21	2.35	2.47	2.62	2.25	2.19	2.35
T_4	3.09	3.16	3.23	3.31	3.14	2.98	3.15
T_5	7.42	7.57	7.80	8.00	7.28	7.14	7.54
T_6	7.35	7.46	7.52	7.68	6.97	6.79	7.30
T_7	2.45	2.52	2.64	2.83	2.64	2.48	2.59
T_8	2.30	2.40	2.57	2.78	2.51	2.31	2.48
T_9	6.68	6.82	7.08	7.28	7.14	7.01	7.00
T_{10}	6.22	6.32	6.54	6.80	6.53	6.39	6.47
T_{11}	3.13	3.22	3.34	3.52	3.88	3.21	3.38
T_{12}	6.46	6.67	6.88	7.08	7.01	6.91	6.84
Mean	5.01	5.13	5.34	5.65	5.36	5.15	5.28
SEd	**0.227**	**0.233**	**0.242**	**0.258**	**0.246**	**0.239**	**-**
CD (0.05)	**0.472**	**0.483**	**0.502**	**0.536**	**0.510**	**0.496**	**-**

Table 48.Effect of chosen treatments on peroxidase activity (Δ430 nm g^{-1} min^{-1}) - (Trial - I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	0.94	1.09	1.41	1.61	1.89	1.89	1.47
T_2	3.12	3.35	3.99	4.13	4.31	4.43	3.89
T_3	0.32	0.51	0.61	0.66	0.77	0.79	0.61
T_4	0.40	0.59	0.59	0.62	0.65	0.67	0.59
T_5	2.05	2.23	2.43	2.59	2.63	2.70	2.44
T_6	1.47	1.99	2.10	2.29	2.34	2.45	2.11
T_7	1.21	1.44	1.57	1.69	1.77	1.87	1.59
T_8	0.47	0.68	0.71	0.80	0.82	0.92	0.73
T_9	3.19	3.88	4.13	4.30	4.31	4.43	4.04
T_{10}	1.88	2.11	2.33	2.50	2.53	2.60	2.32
T_{11}	0.68	0.88	0.99	1.10	1.11	1.22	1.00
T_{12}	2.11	2.34	2.65	2.73	2.75	2.89	2.58
Mean	1.49	1.76	1.96	2.08	2.16	2.24	1.95
SEd	**0.073**	**0.086**	**0.095**	**0.100**	**0.104**	**0.108**	**-**
CD (0.05)	**0.152**	**0.172**	**0.197**	**0.208**	**0.215**	**0.224**	**-**

Table 49. Effect of chosen treatments on peroxidase activity - (Δ430 nm g^{-1} min^{-1}) (Trial – II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	1.09	1.24	1.56	1.75	2.04	2.18	1.64
T_2	3.30	3.53	4.10	4.30	4.49	4.60	4.05
T_3	0.49	0.68	0.79	0.84	0.95	0.97	0.79
T_4	0.62	0.71	0.72	0.83	0.88	0.90	0.78
T_5	2.22	2.40	2.61	2.76	2.80	2.87	2.61
T_6	1.62	2.13	2.26	2.45	2.49	2.69	2.27
T_7	1.35	1.59	1.72	1.83	1.92	2.03	1.74
T_8	0.66	0.87	0.92	0.97	1.01	2.11	1.09
T_9	3.34	4.05	4.282	4.42	4.42	4.68	4.20
T_{10}	2.07	2.28	2.52	2.68	2.72	2.76	2.51
T_{11}	0.86	1.06	1.15	1.27	1.27	1.42	1.17
T_{12}	2.27	2.50	2.80	2.90	2.94	3.03	2.74
Mean	1.66	1.92	2.12	2.25	2.33	2.52	2.13
SEd	**0.077**	**0.089**	**0.098**	**0.102**	**0.105**	**0.110**	**-**
CD (0.05)	**0.159**	**0.184**	**0.203**	**0.212**	**0.218**	**0.229**	**-**

Table 50. Effect of chosen treatments on metabolically active iron content (ppm) - (Trial – I)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	11.34	11.58	11.84	12.23	12.43	12.57	12.00
T_2	44.60	27.52	25.70	29.30	65.50	69.50	43.69
T_3	18.50	19.20	22.10	20.20	24.10	25.50	21.60
T_4	16.80	17.11	18.60	18.00	22.50	24.00	19.50
T_5	49.80	40.64	34.70	22.70	32.30	35.10	35.87
T_6	21.00	21.76	22.10	16.90	34.20	38.50	25.74
T_7	36.90	30.75	22.10	25.70	37.80	40.00	32.21
T_8	17.10	16.20	15.80	16.50	22.90	24.20	18.78
T_9	38.50	37.60	43.00	45.50	46.10	48.54	43.21
T_{10}	33.90	32.45	31.80	30.00	43.00	45.10	36.04
T_{11}	20.70	18.65	22.89	20.85	24.80	25.90	22.30
T_{12}	34.20	30.95	32.20	31.50	48.30	49.00	37.69
Mean	28.61	25.37	25.24	24.12	34.49	36.49	29.05
SEd	**2.584**	**1.090**	**1.074**	**1.042**	**1.484**	**1.571**	**-**
CD (0.05)	**3.512**	**2.260**	**2.228**	**2.162**	**3.077**	**3.257**	**-**

Table 51. Effect of chosen treatments on metabolically active iron content (ppm) - (Trial II)

Treatments	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1	11.79	12.16	12.00	12.72	13.05	13.27	12.50
T_2	45.94	28.35	26.47	30.18	67.47	71.59	45.00
T_3	19.24	19.97	22.98	21.01	25.06	26.52	22.46
T_4	17.34	17.64	19.16	18.54	23.18	24.75	20.10
T_5	51.80	42.27	36.09	23.60	33.59	36.50	37.31
T_6	21.63	22.40	22.75	17.40	35.25	39.65	26.51
T_7	38.02	31.95	22.98	26.73	39.30	41.60	33.43
T_8	17.62	16.69	16.27	16.00	23.50	24.95	19.17
T_9	35.59	32.03	33.43	32.60	49.98	50.72	39.06
T_{10}	35.32	33.80	33.15	31.25	44.80	46.95	37.55
T_{11}	21.49	19.36	23.76	21.64	25.74	26.88	23.15
T_{12}	40.07	39.14	44.75	47.37	47.90	50.55	44.96
Mean	29.65	26.31	26.15	24.92	35.74	37.83	30.10
SEd	**1.279**	**1.116**	**1.099**	**1.066**	**1.525**	**1.616**	**-**
CD (0.05)	**2.653**	**2.315**	**2.280**	**2.210**	**3.162**	**3.352**	**-**

Table 52. Effect of chosen treatments on Fe/ Mn ratio in root - (Trial – I)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	116.39	113.35	108.34	112.69
T_2	84.21	81.93	78.12	81.42
T_3	98.27	96.43	92.74	95.81
T_4	95.21	93.71	91.26	93.39
T_5	64.07	63.46	60.27	62.60
T_6	76.20	70.22	67.34	71.25
T_7	66.32	63.29	60.22	63.28
T_8	96.46	93.27	89.97	93.23
T_9	65.24	62.32	60.42	62.66
T_{10}	62.24	59.91	58.82	60.32
T_{11}	112.36	108.46	107.81	109.54
T_{12}	67.73	64.02	59.20	63.65
Mean	83.72	80.86	77.88	80.82
SEd	**3.651**	**3.526**	**3.390**	**-**
CD (0.05)	**7.573**	**7.312**	**7.030**	**-**

Table 53. Effect of chosen treatments on Fe/Mn ratio in root - (Trial – II)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	118.72	115.60	110.50	114.94
T_2	85.90	83.55	79.60	83.02
T_3	101.35	98.3	94.60	98.08
T_4	97.10	95.60	93.10	95.27
T_5	65.30	64.35	61.45	63.70
T_6	77.75	71.60	68.60	72.65
T_7	67.60	64.25	61.40	64.42
T_8	98.25	95.03	91.75	95.01
T_9	66.50	63.64	61.28	63.81
T_{10}	63.50	61.15	59.42	61.36
T_{11}	114.7	110.2	108.69	111.20
T_{12}	69.10	65.25	60.42	64.92
Mean	85.48	82.38	79.23	82.36
SEd	**3.339**	**3.209**	**3.086**	**-**
CD (0.05)	**6.926**	**6.657**	**6.400**	**-**

Table 54. Effect of chosen treatments on Fe/Mn ratio in soil - (Trial-I)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	139.67	124.68	113.75	126.03
T_2	101.05	90.12	82.02	91.06
T_3	117.92	106.07	97.37	107.12
T_4	114.25	103.08	95.82	104.38
T_5	76.20	69.80	63.28	69.76
T_6	91.44	77.24	70.70	79.79
T_7	79.58	69.61	63.23	70.80
T_8	115.75	102.59	94.46	104.26
T_9	78.28	68.55	63.44	70.09
T_{10}	74.68	65.9	61.76	67.44
T_{11}	134.83	119.3	113.2	122.44
T_{12}	81.27	70.42	62.16	71.28
Mean	100.41	88.94	81.76	90.37
SEd	**4.301**	**3.878**	**3.558**	-
CD (0.05)	**8.920**	**8.043**	**7.379**	-

Table 55. Effect of chosen treatments on Fe/Mn ratio in soil - (Trial – II)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	141.75	126.50	115.45	127.90
T_2	102.50	91.45	83.30	92.42
T_3	119.70	107.65	98.80	108.72
T_4	115.95	104.60	97.23	105.93
T_5	77.30	70.85	64.20	70.78
T_6	92.80	78.04	71.75	80.86
T_7	80.70	70.60	64.15	71.82
T_8	118.05	104.10	96.85	106.33
T_9	79.37	69.50	64.40	71.09
T_{10}	75.70	67.22	62.65	68.52
T_{11}	136.85	121.10	114.90	124.28
T_{12}	82.05	71.56	63.10	72.24
Mean	101.89	90.26	83.07	91.74
SEd	**3.979**	**3.517**	**3.235**	-
CD (0.05)	**8.253**	**7.293**	**6.710**	-

Table 56.Effect of chosen treatments on P/Fe ratio in root - (Trial - I)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	0.160	0.201	0.223	0.195
T_2	0.106	0.133	0.148	0.129
T_3	0.166	0.208	0.232	0.202
T_4	0.104	0.131	0.145	0.127
T_5	0.109	0.137	0.153	0.133
T_6	0.157	0.197	0.219	0.191
T_7	0.115	0.144	0.160	0.140
T_8	0.147	0.184	0.204	0.178
T_9	0.095	0.119	0.132	0.115
T_{10}	0.169	0.212	0.235	0.205
T_{11}	0.170	0.213	0.237	0.207
T_{12}	0.162	0.203	0.226	0.197
Mean	0.138	0.174	0.193	0.168
SEd	**0.007**	**0.009**	**0.009**	**-**
CD (0.05)	**0.014**	**0.018**	**0.018**	**-**

Table 57. Effect of chosen treatments on P/Fe ratio in root - (Trial – II)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	0.124	0.155	0.173	0.151
T_2	0.158	0.198	0.220	0.192
T_3	0.118	0.148	0.164	0.143
T_4	0.112	0.140	0.156	0.136
T_5	0.179	0.225	0.251	0.218
T_6	0.169	0.212	0.235	0.205
T_7	0.173	0.215	0.240	0.209
T_8	0.114	0.143	0.160	0.139
T_9	0.184	0.230	0.255	0.223
T_{10}	0.255	0.231	0.254	0.247
T_{11}	0.105	0.131	0.142	0.126
T_{12}	0.168	0.215	0.244	0.209
Mean	0.155	0.187	0.208	0.183
SEd	**0.744**	**0.009**	**0.009**	-
CD (0.05)	**1.544**	**0.019**	**0.019**	-

Table 58. Effect of chosen treatments on P/Fe ratio in soil - (Trial – I)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	0.192	0.221	0.234	0.216
T_2	0.176	0.202	0.214	0.197
T_3	0.131	0.151	0.161	0.148
T_4	0.124	0.144	0.152	0.140
T_5	0.199	0.229	0.243	0.224
T_6	0.188	0.217	0.230	0.212
T_7	0.138	0.158	0.168	0.155
T_8	0.127	0.146	0.155	0.143
T_9	0.204	0.234	0.249	0.229
T_{10}	0.202	0.233	0.247	0.227
T_{11}	0.114	0.130	0.139	0.128
T_{12}	0.194	0.223	0.237	0.218
Mean	0.166	0.191	0.202	0.186
SEd	**0.008**	**0.008**	**0.008**	**-**
CD (0.05)	**0.017**	**0.017**	**0.018**	**-**

Table 59. Effect of chosen treatments on P/Fe ratio in soil - (Trial – II)

Treatments	150 DAP	210 DAP	270 DAP	Mean
T_1	0.140	0.161	0.170	0.157
T_2	0.175	0.205	0.217	0.199
T_3	0.135	0.154	0.165	0.151
T_4	0.126	0.145	0.155	0.142
T_5	0.203	0.235	0.233	0.224
T_6	0.191	0.220	0.235	0.215
T_7	0.195	0.225	0.238	0.219
T_8	0.130	0.147	0.155	0.144
T_9	0.205	0.235	0.255	0.232
T_{10}	0.207	0.233	0.252	0.231
T_{11}	0.115	0.130	0.242	0.162
T_{12}	0.195	0.225	0.240	0.220
Mean	0.168	0.193	0.213	0.191
SEd	**0.007**	**0.009**	**0.009**	**-**
CD (0.05)	**0.014**	**0.018**	**0.018**	**-**

Table 60. Effect of chosen treatments on number (lakh ha^{-1}), weight (Kg), height (cm) of millable cane at harvest- (Trial –I)

Treatments	No.of millable cane (lakh ha^{-1})	Weight of millable cane (Kg)	Height of millable cane (cm)
T_1	0.95	1.10	211
T_2	1.00	1.32	243
T_3	0.96	1.15	222
T_4	0.97	1.20	234
T_5	0.98	1.23	246
T_6	0.99	1.25	244
T_7	1.00	1.43	250
T_8	0.96	1.18	223
T_9	1.03	1.60	275
T_{10}	0.99	1.27	241
T_{11}	0.98	1.21	236
T_{12}	1.00	1.53	255
Mean	0.98	1.29	240
SEd	**0.006**	**0.008**	**1.270**
CD (0.05)	**0.013**	**0.017**	**2.630**

Table 61. Effect of chosen treatments on number (lakh/ha), weight (kg), and height of millable (cm) cane at harvest - (Trial –II)

Treatments	No.of millable cane (lakh/ha)	Weight of millable cane (kg)	Height of millable cane(cm)
T_1	0.970	1.120	215
T_2	1.015	1.350	248
T_3	0.978	1.174	227
T_4	0.991	1.220	239
T_5	1.001	1.254	251
T_6	1.012	1.280	249
T_7	1.019	1.450	255
T_8	0.983	1.210	227
T_9	1.045	1.650	280
T_{10}	1.013	1.290	246
T_{11}	0.995	1.240	241
T_{12}	1.028	1.560	260
Mean	1.004	1.317	245
SEd	**0.039**	**0.053**	**9.578**
CD (0.05)	**0.081**	**0.107**	**19.863**

Table 62. Effect of chosen treatments on girth (cm), number and average length (cm) of internodes at harvest - (Trial I)

Treatments	Cane girth (cm)	No. of internodes	Average length of internodes (cm)
T_1	2.58	19.01	11.09
T_2	2.90	20.83	11.65
T_3	2.60	20.00	11.11
T_4	2.71	20.16	11.60
T_5	2.78	20.33	12.10
T_6	2.83	20.62	11.83
T_7	2.94	21.80	11.69
T_8	2.64	20.10	11.09
T_9	2.99	22.00	12.50
T_{10}	2.88	20.66	11.67
T_{11}	2.74	20.20	11.68
T_{12}	2.91	20.88	11.97
Mean	2.79	20.55	11.67
SEd	**0.016**	**0.116**	**0.481**
CD (0.05)	**0.033**	**0.240**	**-**

Table 63. Effect of chosen treatments on girth (cm), number and average length of internodes (cm) at harvest - (Trial – II)

Treatments	Cane girth (cm)	No. of internodes	Average length of internodes (cm)
T_1	2.63	19.40	16.35
T_2	2.96	21.10	21.10
T_3	2.67	20.40	17.20
T_4	2.78	20.52	19.10
T_5	2.83	20.74	19.65
T_6	2.87	21.05	20.32
T_7	2.97	20.97	20.32
T_8	2.70	20.52	17.58
T_9	3.07	21.45	22.98
T_{10}	2.94	21.05	21.07
T_{11}	2.80	20.63	19.51
T_{12}	2.99	21.25	21.35
Mean	2.85	20.76	19.71
SEd	**0.110**	**0.806**	**0.774**
CD (0.05)	**0.230**	**N.S**	**1.605**

Table 64.Effect of chosen treatments on juice quality parameters at harvest - (Trial – I)

Treatments	Brix %	Sucrose % (Pol)	Purity co-efficient (%)	Reducing sugars (%)	CCS (%)
T_1	19.63	18.07	92.05	0.58	11.58
T_2	20.24	18.22	90.20	0.40	11.9
T_3	21.11	19.04	90.19	0.46	13.14
T_4	19.56	19.81	87.79	0.44	12.39
T_5	21.10	19.44	92.13	0.47	12.85
T_6	21.61	19.00	87.92	0.47	13.13
T_7	22.27	19.86	87.06	0.36	13.49
T_8	21.00	16.96	80.76	0.49	13.18
T_9	23.21	21.04	90.25	0.37	13.90
T_{10}	20.34	18.73	92.08	0.50	12.25
T_{11}	21.19	19.03	89.80	0.47	10.35
T_{12}	22.81	20.10	90.06	0.42	13.70
Mean	21.74	19.11	89.19	0.45	12.66
SEd	**0.878**	**0.790**	**3.699**	**0.019**	**0.533**
CD (0.05)	**1.820**	**1.638**	**N.S**	**0.038**	**1.105**

Table 65. Effect of chosen treatments on juice quality parameters at harvest- (Trial – II)

Treatments	Brix %	Sucrose % (Pol)	Purity co-efficient (%)	Reducing sugars (%)	CCS (%)
T_1	19.82	18.25	92.97	0.48	11.85
T_2	20.44	18.40	91.10	0.51	12.13
T_3	21.32	19.23	91.10	0.46	13.82
T_4	22.72	19.44	88.65	0.44	12.65
T_5	21.31	19.63	93.06	0.47	13.57
T_6	21.83	19.20	88.80	0.47	13.82
T_7	22.50	21.25	90.97	0.39	13.93
T_8	21.20	17.13	81.55	0.49	13.44
T_9	23.45	20.28	91.10	0.37	15.94
T_{10}	20.55	18.90	93.03	0.51	12.50
T_{11}	21.41	19.20	90.70	0.48	10.55
T_{12}	23.04	20.06	87.90	0.42	14.15
Mean	21.50	19.25	90.08	0.46	13.20
SEd	**0.838**	**0.753**	**3.495**	**0.017**	**0.520**
CD (0.05)	**1.737**	**1.562**	**N.S**	**0.035**	**1.079**

Table 66. Effect of chosen treatments on cane yield (t ha^{-1}), and sugar yield (t ha^{-1}) - (Trial – I)

Treatments	Cane yield (t ha^{-1})	Sugar yield (t ha^{-1})
T_1	60.42	7.69
T_2	99.40	13.10
T_3	72.88	10.75
T_4	76.52	11.09
T_5	92.00	14.14
T_6	93.11	15.05
T_7	110.11	15.36
T_8	74.70	9.98
T_9	121.11	16.83
T_{10}	96.09	11.27
T_{11}	81.88	9.63
T_{12}	116. 55	15.47
Mean	91.23	12.53
SEd	**0.686**	**0.527**
CD (0.05)	**1.422**	**1.094**

Table 67. Effect of chosen treatments on cane yield (t ha^{-1}) and sugar yield (t ha^{-1}) - (Trial – II)

Treatments	Cane yield (t ha^{-1})	Sugar yield (t ha^{-1})
T_1	60.42	7.16
T_2	93.70	11.36
T_3	72.80	10.06
T_4	76.52	9.67
T_5	92.00	12.48
T_6	93.10	12.86
T_7	95.42	13.29
T_8	74.70	10.03
T_9	121.10	11.30
T_{10}	96.04	12.00
T_{11}	81.80	8.62
T_{12}	101.34	14.83
Mean	88.25	11.81
SEd	**3.767**	**0.519**
CD (0.05)	**7.812**	**1.075**

Table 68. Association among morpho-physiological characters and cane yield as influenced by the chosen treatments

Characters	LAI	LAD	CGR	NAR	SLW	CY
LAI	1					
LAD	0.966**	1				
CGR	0.872**	0.874**	1			
NAR	0.911**	0.850**	0.950**	1		
SLW	0.534**	0.529**	0.170	0.270	1	
CY	0.881**	0.834**	0.952**	0.965**	0.179	1

LAI - Leaf area index

LAD- Leaf area duration

NAR-Net assimilation rate

CGR- Crop growth rate

SLW- Specific leaf weight

CY- Cane yield

Table 69 .Association among physiological / biochemical characters and cane yield as influenced by the chosen treatments

Characters	PR	SPAD	T.chll	Chll'a'	Chll'b'	Sol.Pn	Fv/Fm	Fe/Mn(rts)	P/Fe(rts)	MAI	CEC	CY
PR	1											
SPAD	0.839**	1										
T.chll	0.339*	0.339*	1									
Chll'a'	0.574**	0.480**	0.979**	1								
Chll'b'	0.282	0.031**	0.878**	0.803**								
SP	0.488**	0.544**	0.460**	0.551**	0.273	1						
Fv/Fm	0.948**	0.921**	0.545**	0.656**	0.240	0.521**	1					
Fe/Mn(rts)	-0.413**	-0.491**	-0.099	-0.228	0.180	-0.533**	-0.466**	1				
P/Fe(rts)	0.701**	0.662**	0.311	0.429**	0.027	0.455**	0.735**	-0.863**	1			
MAI	0.423**	0.432**	0.411*	0.435**	0.159	0.517**	0.476**	-0.630**	0.691**	1		
CEC	0.704**	0.723**	0.694**	0.775**	0.424	0.647**	0.778**	-0.649**	0.802**	0.750**	1	
CY	0.648**	0.789**	0.407*	0.527**	0.101	0.736**	0.739**	-0.763**	0.815**	0.785**	0.892**	1

PR- Photosynthetic rate

SPAD-Chlorophyll meter readings

T.Chll- Total chlorophyll

Chl'a'-Chlorophyll 'a'

Chl 'b'- Chlorophyll 'b'

SP-Soluble protein

Fv/Fm- Chlorophyll fluorescence

Fe/Mn(rts)-Iron/Manganese ratio in roots

P/Fe(rts)- Phosphorus/Iron ratio in roots

MAI-Metabolically active iron

CEC- Cation exchange capacity

CY-Cane yield

Table 70. Association among yield attributes and cane yield as influenced by the chosen treatments

Characters	CG	CH	NOI	NMC	ALI	TC	CCS	SY	CY
CG	1								
CH	0.935**	1							
NOI	0.946**	0.904**	1						
NMC	0.915**	0.837**	0.941**	1					
ALI	0.896**	0.918**	0.880**	0.934**	1				
TC	0.394*	0.347*	0.482**	0.435**	0.349*	1			
CCS	0.655**	0.734**	0.666**	0.668**	0.782**	0.071	1		
SY	0.805**	0.903**	0.728**	0.572**	0.689**	0.187	0.661**	1	
CY	0.846**	0.900**	0.760**	0.606**	0.678**	0.270	0.528**	0.975**	1

CG-Cane girth

CH- Cane height

ALI-Average length of internodes

CCS- Commercial cane sugar

CY-Cane yield

NOI- Number of internodes

NMC- Number of millable canes

TC- Tillering capacity

SY- Sugar yield

Fig 1. Layout of experimental field (Trial I)

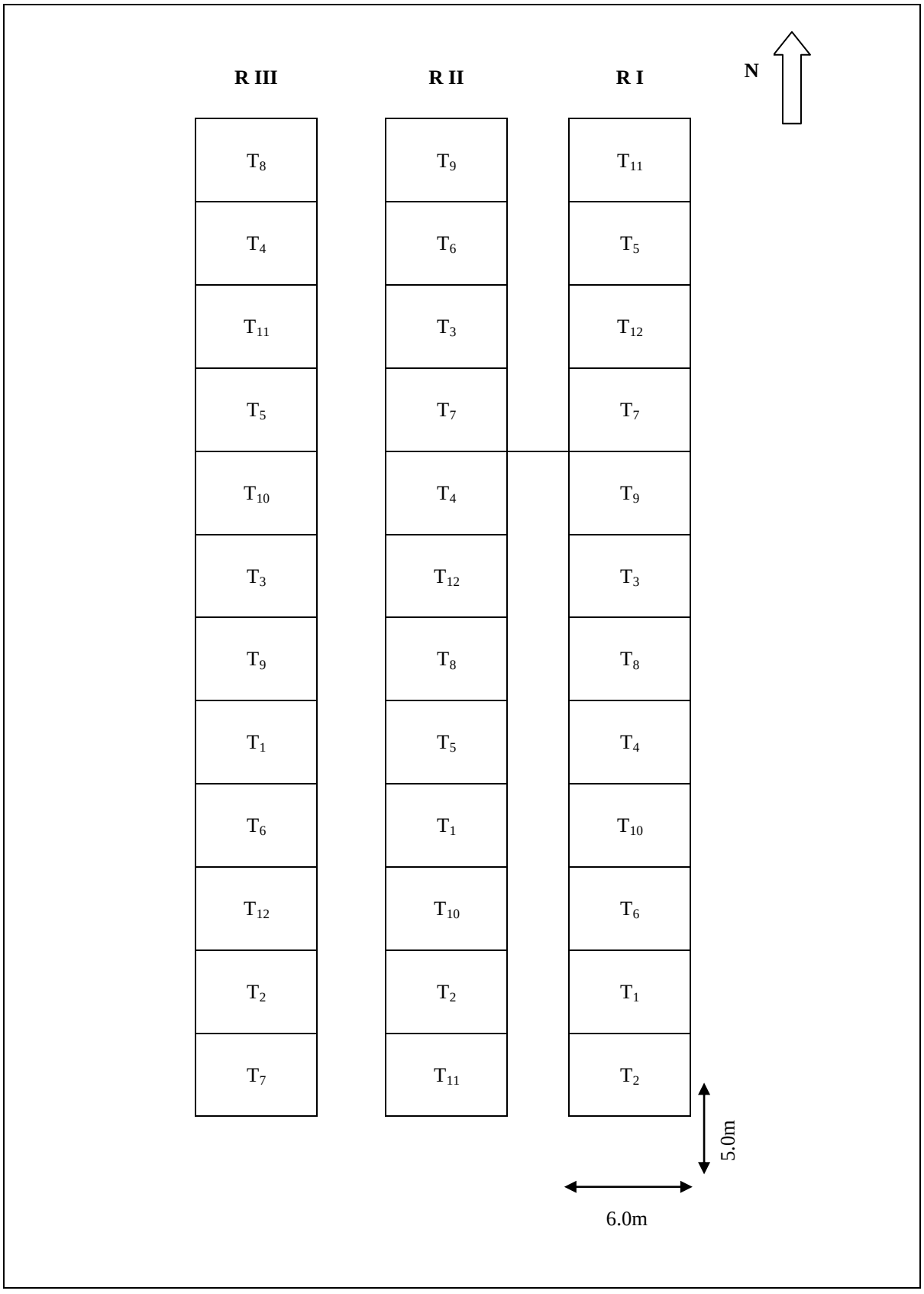


Fig 2. Layout of experimental field (Trial II)

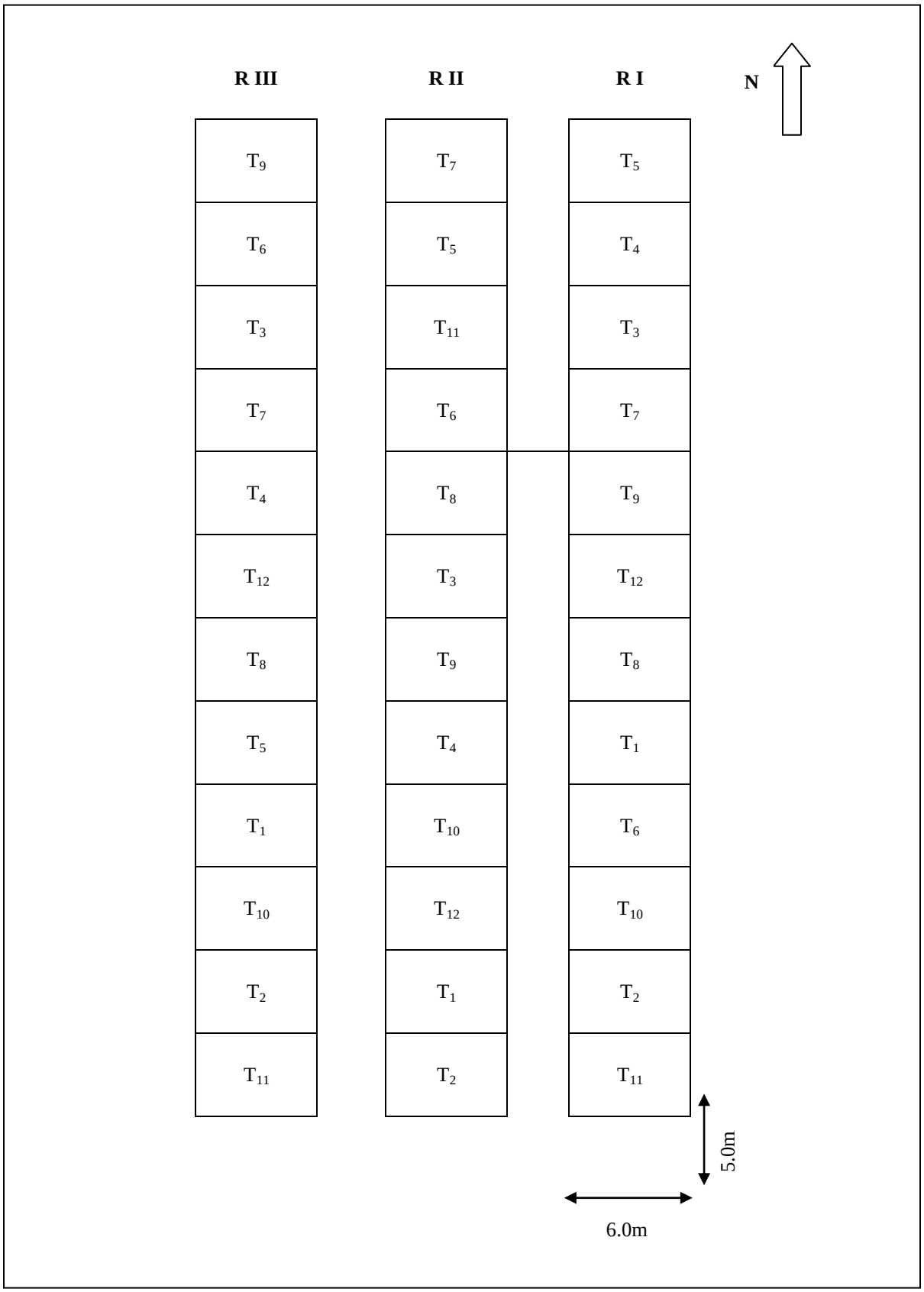


Table 5. Weather parameters during the cropping period (January - December, 2007)

Standard Week	Period	Temperature (^{o}C)		Relative humidity (%)		Rainfall (mm)	Rainy days (No.)	Mean sunshine (Hrs day $^{-1}$)	Mean solar radiation (Cal. cm^{-2} day $^{-1}$)
		Max	Min	7.22 (Hrs)	14.22 (Hrs)				
1	1-7 Jan	29.1	17.1	90	43	-	-	8.7	457.6
2	8-14	29.2	19.5	88	47	-	-	6.5	390.7
3	15-21	30.4	18.8	90	37	-	-	7.0	442.5
4	22-28	30.8	18.7	87	39	10.0	1	8.1	455.2
5	29-4 Feb	30.0	19.5	90	41	-	-	7.2	402.0
6	5-11	31.4	18.8	78	34	-	-	9.2	438.6
7	12-18	32.8	19.1	88	40	-	-	9.5	448.7
8	19-25	30.9	19.3	84	34	-	-	9.2	465.1
9	26-4 Mar	33.5	19.0	88	42	21.8	1	73.9	407.1
10	5-11	33.6	21.5	75	30	-	-	10.1	463.7
11	12-18	33.7	22.6	82	36	-	-	9.8	442.2
12	18-25	36.2	20.1	84	27	-	-	10.3	466.4

Standard	Period	Temperature (^{o}C)	Relative humidity (%)	Rainfall	Rainy	Mean sunshine	Mean solar

Week		Max	Min	7.22 (Hrs)	14.22 (Hrs)	(mm)	days (No.)	(Hrs day $^{-1}$)	radiation (Cal. cm^{-2} day $^{-1}$)
13	26-1Apr	35.9	22.6	80	31	-	-	9.6	445.5
14	2-8	36.4	24.3	85	31	-	-	9.7	444.6
15	9-15	35.2	23.7	84	40	-	-	7.4	387.0
16	16-22	34.4	23.0	86	46	27.0	3	8.2	407.4
17	23-29	35.4	24.0	88	44	2.2	1	9.6	427.9
18	30-6 May	34.8	23.9	90	52	-	-	8.3	394.7
19	7-13	34.1	24.0	87	48	-	-	9.6	431.7
20	14-20	35.5	23.1	83	38	45.8	1	10.4	454.4
21	21-27	35.6	23.8	88	48	1.2	-	8.0	381.0
22	28-3 June	33.1	23.6	74	46	36.8	4	7.8	426.1
23	4-10	34.7	23.9	83	48	0.2	-	8.0	421.2
24	11-17	33.1	23.7	81	52	3.2	1	7.9	417.1
25	18-24	29.3	23.3	74	62	12.6	2	0.9	236.1

Standard Week	Period	Temperature (^{o}C)		Relative humidity (%)		Rainfall (mm)	Rainy days (No.)	Mean sunshine (Hrs day $^{-1}$)	Mean solar radiation (Cal. cm^{-2} day $^{-1}$)
		Max	Min	7.22 (Hrs)	14.22 (Hrs)				
26	25-1 July	29.5	23.4	83	65	32.4	2	2.9	294.0
27	2-8	28.7	23.6	79	66	46.7	4	2.4	264.9
28	9-15	30.1	24.0	74	60	1.8	-	5.3	375.0
29	16-22	30.1	22.6	90.5	63	17.7	2	4.8	339.4
30	23-29	29.6	22.4	92	64	3.4	1	2.1	305.1
31	30-5 Aug	29.3	22.4	97	67	6.3	1	1.9	254.2
32	6-12	28.7	22.7	85	61	31.8	3	3.6	245.5
33	13-19	32.2	21.9	91	49	-	-	8.3	422.6
34	20-26	30.8	22.1	94	63	46.0	2	4.7	307.6
35	27-2 Sept	30.9	22.9	85	58	0.6	-	4.7	321.7
36	3-9	31.3	22.8	84	52	0.2	-	4.7	359.9
37	10-16	32.1	23.0	91	56	7.2	1	6.1	328.9

38	17-23	30.5	23.9	80	58	9.2	1	3.4	321.9

Standard Week	Period	Temperature (^{o}C)		Relative humidity (%)		Rainfall (mm)	Rainy days (No.)	Mean sunshine (Hrs day $^{-1}$)	Mean solar radiation (Cal. cm^{-2} day $^{-1}$)
		Max	Min	7.22 (Hrs)	14.22 (Hrs)				
39	24-30	31.2	22.8	86	54	8.0	2	6.6	341.8
40	1-7 Oct	32.2	21.4	80	45	-	-	10.1	410.3
41	8-14	33.0	23.1	91	49	43.4	1	5.2	348.7
42	15-21	30.0	23.0	94	65	52.8	3	5.4	262.9
43	22-28	28.0	22.2	96	70	30.0	4	2.4	237.5
44	29- 4Nov	28.9	21.8	94	68	173.0	5	4.0	250.6
45	5-17	29.8	21.7	93	58	139.0	1	3.3	410.6
46	12-18	29.7	22.1	90	69	14.5	-	3.5	464.4
47	19-25	29.5	22.0	87	54	45.0	2	3.4	406.9
48	26-2 Dec	29.4	21.6	87	53	0.4	-	6.4	394.7
49	3-9	28.4	18.6	86	54	-	-	7.8	374.6

50	10-16	28.9	20.1	89	53	0.6	-	7.1	315.0

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C Ratio
T_1- Control	77130	68455	-8675	0.89
T_2- 1 % $FeSO_4$ spray	92070	1,06,159	14088	1.15
T_3- 1 ppm Brasssinolide spray	84765	82572	- 2192	0.97
T_4- 150 ppm Salicylic Acid spray	84470	86700	2230	1.03
T_5- 1 %$FeSO_4$ +0.5 % $ZnSO_4$ spray	89660	1,04236	14576	1.16
T_6- 1 %$FeSO_4$ + 0.5 % $MnSO_4$ spray	92085	1,05494	13409	1.14
T_7- 1 %$FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ spray	92450	1,08,121	15671	1.17
T_8- 1 ppm Brasssinolide + Salicylic Acid spray	85397	84635	- 762	0.99
T_9- 1 %$FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + Brasssinolide spray	1,16 671	1,42,741	26170	1.27
T_{10}- 1 %$FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % ZnSO4 + Brasssinolide + Salicylic Acid spray	91190	1,08870	17680	1.19
T_{11}- Micronutrient mixture @ 5 Kg soil application	86271	92770	6489	1.07
T_{12}- Micronutrient mixture @ 5 Kg soil application + 1 ppm Brasssinolide + 150 ppm Salicylic Acid spray	95380	1,14,827	19446	1.20

Table 71. Economics of chosen treatments on the B: C ratio

REFERENCES

Abadia, J. and A.Abadia.1993. Iron and plant pigments. In: Iron chelation in plants and soil microorganisms. Edn. L. L Barton and B.C Henning. pp 327 - 343. Academic Press. San Diego, CA.

Abadıa, J., J.N. Nishio, E. Monge, L. Montanes and L. Heras. 1985. Mineral composition of peach tree leaves affected by iron chlorosis. **J. Plant Nutr., 8:** 697 – 708.

Agarwal, M.P. and N.C. Lal. 1987. Use of pyrite, press mud, ammonium sulphate and sulphur for the amelioration of lime induced chlorosis of sugarcane in vertisols. **Hort. Abstr. 59:** 610.

Agarwala, S.C., B.K. Sinha, C. Chatterjee and C.P. Sharma. 1976. Dependence of iron utilization by rice on nitrogen source in growth medium. **Geophytology, 6**: 341-349.

Agarwala, S.C., C.P. Sharma and A. Kumar.1964. Inter relationship of iron and manganese supply in growth, chlorophyll and iron porphyrin enzymes in barley plants. **Plant Physiol., 39**: 603 - 609.

Agarwala, S.C., C.P. Sharma and S. Farooq.1965. Effect of iron on supply growth, chlorophyll, tissue iron and activity of certain enzymes in maize and radish. **Plant Physiol., 40:** 493 - 499.

Ahmed, M.1977. Effect of secondary and micronutrient application on sugarcane crop. Hyesons Sugar Mills Khanpur. **Proc.14th Ann. Conv. Pak. Soc. Sugar Technol**. pp 130 - 133.

Aiyer, S.P. 1946. The place of minor elements in rice growing areas. **Indian Fmg., 7:** 487 - 490.

Altaf Ahmed, A.S., K.T. Narasimham, N. Ramamurthy, S. Swamyprakasam and S.D. Rajan. 1975. Studies on the efficacy of micronutrient application for sugarcane in Cuddalore tract. **Indian Sug., 25 :** 395 - 399.

Alvarez-Fernandez, A., Garcia-Marco, S., Lucena J.J. 2005. Evaluation of synthetic iron (III)-chelates (EDDHA/Fe^{3+}, EDDHMA/Fe^{3+} and the novel EDDHSA/Fe^{3+}) to correct iron chlorosis. **Europ. J. Agronomy,** 22**:** 119-130.

Anonymous, 1973. Tech. Rep. 1972-73. All India Co-ordinated research project on sugarcane. IISR, Lucknow.

Anonymous, 1984. Final report of Adhoc scheme on cause and correction of chlorosis in sugarcane, turmeric, jasmine and crossandra (1981-84). Tamil Nadu Agricultural University, Coimbatore.

Anonymous, 2005. Sugar statistics. **Co-op**. **Sugar, 36:**1007.

Anonymous.1983. Mineral nutrition of sugarcane. **Ann. Rep. Instt. Rech. Agron. Trop. (IRAT):** 45 - 52**.**

Anuradha., S and S.Seeta Rama Rao.2007. Effect of 24-epibrassinolide on the growth and antioxidant enzyme activities in radish seedlings under lead toxicity. **Indian J. Plant Physiol., 12 :** 396 - 400.

Arulanantham, A.R., I.M. Rao and N. Terry.1990. Limiting factors in photosynthesis. VI. Regeneration of ribulose bi, 5- phosphate limits photosynthesis at low photosynthesis activity. **Plant Physiol., 93:** 1466 - 1475.

Bailey, L.F and J.S. Mc.Hargue. 1944. Effect of boron, copper, manganese and zinc on the enzyme activity of tomato and alfalfa plants grown in the green house. **Plant Physiol., 19 :** 105 - 108.

Bangar, K.S. and S.R. Sharma. 1992. Effect of foliar application of micronutrients on growth, yield and quality of sugarcane**. Indian Sug**., **42** : 211 - 213.

Banger, K.S., S.R. Sharma and R.K. Sharma. 1991. Effect of iron and zinc on yield and quality of sugarcane**. Indian Sug., 41** : 403 - 404.

Baversco, L., H. Fregoni, and P.Fraschini.1992. Investigations on some physiological parameters involved in chlorosis occurrence in grafted grapevine. **J. Plant Nutr., 15** : 1791 - 1807.

Beale, S.I. 1999. Enzymes of chlorophyll biosynthesis. **Photosynth. Res., 60**: 43-73.

Beauchamp, C.O and I. Fredovich. 1971. Superoxide dismutase. Improved assays and an assay applicable to acryl amide gels. **Anal. Biochem., 44:** 276 - 287.

Bennet, J.P. 1945. Iron in leaves. **Soil Sci., 60:** 91-105.

Bhardwaj, S.N., M.Singh, V.P. Singh and K.P. Singh. 1987. Leaf area, its thickness and conductance in the genotypes of upland cotton. **Indian J. Agric. Sci., 56:** 840 -843.

Bhatia, D.S and J.Kaur.1997. Effect of BR and humicil in chlorophyll content, hill activity and yield components in mung bean (*Vigna radiata* (L,) Wilczek.). **Phytomorp., 47** : 412 - 426.

Bindhu Joseph.2000. Physiological and biochemical effects of Brassinolide on the productivity of groundnut. **M.Sc. (Ag.) Thesis submitted to Tamil Nadu Agricultural University, Coimbatore.**

Black, C.C. Jr and B.C.Mayne.1970.P 700 activity and chlorophyll content of plants with different photosynthetic carbon dioxide fixation cycle. **Plant Physiol., 45:** 738 -741.

Bowes, G., W.L. Ogren and R.W. Hageman. 1972. Light saturation, photosynthetic rate, RUBP carboxylase activity, and specific leaf weight in soybeans grown under different light intensities. **Crop Sci., 12:** 77 - 79.

Braun, P.and M.Wild.1984. The influence of brasinosteroid on growth and parameters of photosynthesis of wheat and mustard seeds. **J. Plant Physiol., 116:** 189 - 196.

Briggs, G.E., F. Kidd and C.West. 1920. A quantitative analysis of plant growth. **Ann. Appl. Biol., 7:** 103.

Brown, J.C. 1961. Iron chlorosis in plants. **Adv. Agron**., **13:** 329 - 366.

Brown, J.E.1973. Effect of micronutrient deficiencies on macronutrient accumulation in sugarcane. **Trop. Agric., 50:** 129 - 137.

Brown, J.E.1975. Micronutrient composition of sugarcane sheaths as affected by age. **Trop. Agric., 52:** 131-137.

Brownn, J.C. and Hendricks, S.B. 1952. Enzymatic activities as indications of copper and iron deficiencies in plants. **Plant Physiol., 27:** 651 - 660.

Casano, L.M., M. Martin, J.M. Zapata and B. Sabater. 1999. Leaf age and paraquat concentration dependent effects on the level of enzymes protecting against photo oxidative stress. **Plant Sci., 149:** 13 - 22.

Chandrasekaran, P. 1976. Studies on the iron nutrition of groundnut in calcareous and non-calcareous soils. **M.Sc (Ag.) thesis submitted to Tamil Nadu Agricultural University, Coimbatore.**

Chattopadhyay, A., D. Subramanyan, M. Anwar, D.V. Singh and N K. Srivastava. 1989. Nutrient composition and photosynthetic characteristics of chlorotic and normal plants of Japanese mint (*Mentha arvensis*. L.). **Pl. Physiol. and Biochem., 16 :** 163 - 165.

Chen, Y. and P. Barak.1982. Iron nutrition in plants in calcareous soils. **Adv. Agron., 35 :** 217 - 240.

Chhabda, P.R., M.V. Gaybe and S.B. Varda.1980. Root CEC of sorghum cultivars as related to P content. Res. Bull. **Marathwada Agric. Univ., 4:** 15 - 16.

Chiranjivi Rao, K and S.Asokan. 1974. Alkaline potassium ferricyanide method (calorimetric) for direct estimation of reducing sugars in cane juice. **Indian Sug., 23** : 95

Cinelli, F and R. Viti. 1985. Practical use of CEC as a predictive marker of lime induced chlorosis tolerance in (*Prunus cerasifera* L.) rootstocks. **J. Plant Nutr., 18** : 65 -75**.**

Clarkeson, D.T. and J.B. Hanson. 1980. The mineral nutrition of higher plants. **Ann. Rev. Plant Physiol., 31:** 239 - 298.

Clements, 1980. Sugarcane crop logging and crop control: Principles and practices. Pitman Pub. Ltd. London, pp. 241 - 269.

Clements, H.F. 1964. Interaction of factors affecting yield. **Ann. Rev. Pl. Physiol., 15:** 409 - 442.

Cramer, G.R. and R.S. Nowak.1992.Supplemental manganese improves the relative growth, net assimilation and photosynthetic rates of salt stressed barley. **Physiol. Plant**., 84: 600 - 605.

Crook, W.M. 1964.The measurement of cation-exchange capacity of plant roots. **Pl. Soil, 21:** 43 - 49.

Davis, T., V. Jolley, R. Walser, J. Brown and A. Blaylock. 1986. Net photosynthesis of Fe-efficient and Fe-inefficient soybean cultivars grown under varying levels. **J**. **Plant Nutr., 9 :** 671 - 681.

De, R. and H. Singh. 1954. A note on the chlorosis of sugarcane. **Proc. 2nd Bien Congr. Sug. Cane Res. Dev. Workers, 2 :** 862 - 863.

DeKock, P. C. and E. L. Stremecki. 1954. An investigation into the growth promoting effect of lignite. **Physiol. Plant**., **7:** 503 - 512.

DeKock, P.C. 1955. Iron nutrition of plants at high pH. **Soil Sci., 79:** 167 -175.

Dekock, P.C. 1981. Iron nutrition under conditions of stress. **J. Plant Nutr., 3 :** 513 -521.

Del Rio, L. A., M. Gomez, J. Yenez, A. Leal and J. L. George. 1978. Iron deficiency in pea plants. Effects on catalase, peroxidase, chlorophyll and protein of leaves. **Pl. Soil, 49:** 343 - 353.

Dev, C. and M. S. Mann. 1972. Removal of Zn, Cu, Mn and Fe as affected by varying soil fertility levels. **Fert. News**, **17:** 48 - 50.

Dhanasekaran, K. and R. Bhuvaneswari. 2004. Effect of zinc and iron humates application on the yield and quality of sugarcane. **Indian Sug., 54 :** 907 - 912.

Diz, G.S., N. Perez, M. Nunez and W.Torres 1995. Effects of the synthetic brassinosteroid DAA - 6 on tobacco (*Nicotiana tabaccum* L.). **Cultivars –Tropicales**, **16** : 53 - 55

Donald T. Krizek and N.Bhushan Mandava.1983. Influence of spectral quality on the growth responses of intact bean plants to brassinosteroid a growth promoting harmone. I. Stem elongation and morphogenesis. **Physiologia Plantarum, 57:** 317 - 396.

Dwivedi, R. and G.B.Singh.1991. Zinc nutrition of sugarcane. U.P. Zinc sulphate manufacturer's assoc. Lucknow. pp. 12- 13.

Evans, H. 1959. Elements other than N, K and P in the mineral nutrition of sugarcane. **Proc. ISSCT. 10 :** 473 - 508.

Evans, H., R.B.Austin, R.A.Yates and L.A.Forte.1956. Some consideration affecting interpretation of foliar diagnostic analysis under British Guiana conditions. **Proc. Int. Soc. Sug. Cane Technol., 9:** 157 - 171.

Evans, H.1965. Tissue diagnostic analysis and interpretation in sugarcane. **Proc. Int. Soc. Sug. Cane Technol., 12:** 171.

Evans, L.T. 1975. The physiological aspects of crop yield. In: Evans L.T. (ed.). Crop Physiology – Some case Histories, Cambridge Univ. Press, London.

Evans, L.T. 1982. Photosynthetic activity and partitioning. In: Chemistry and world food supplies. The new frontiers, Chemrawm II; Philippines. pp. 6 - 10.

Fogliata, F.A. and V.N. Bustos. 1980. Sugarcane ferric chlorosis in excessive calcareous soils. **Proc. ISSCT, 17**: 262 - 281.

Garg, A.K. and K.D. Agarwal. 1976. A review on causes and remedies of iron chlorosis in sugarcane. **Proc. DSTA Conv., 27:** 41 - 45.

Gitelson,A.A., C.Buschmann and H.K.Lichtenthaler.1999. Leaf chlorophyll fluorescence corrected for reabsorption by means of absorption and reflectance measurements. **J. Plant Physiol., 152 :** 283 - 296.

Gomez, K.A and A.A Gomez. 1984. Statistical procedures for agricultural research (2^{nd} edn.) Intl. Rice.Res. Inst., P.O. Box. Manila, Philippines and John Wiley and Sons, New York, U.S.A. pp - 680.

Gopalachari, N.C.1963. Changes in the activities of certain oxidizing enzymes during germination and seedling development of (*Phaseolus mungo)* and (*Sorghum vulgare)*. **Indian J. Expl. Biol., 1:** 98 - 100.

Goyal, K.N. and R.N.S. Tyagi. 1976. Yellowing disease of sugarcane and its control. **Indian Sug., 25** : 797.

Gregory, F.G. 1926. The effect of climatic conditions on the growth of barley. **Ann. Bot., 40**: 1 - 26.

Gris, E. 1943. Delaction des compositions ferruginouses Fur la Vegetation**. C. R. Acad Sci. (Paris), 17**: 679.

Gris, E.1844. Nouwelles experiences decomposes ferrugineur solubles appliqué a la vegetation et specialemnt en traitlement de la chloroose st de la debilite des plants. **Compt. Rend. Acad. Sci., 19:** 1118 - 1119.

Gupta, A.P. and G.S.C. Rao. 1980. The effect of Mn on growth, total protein and nucleic acid in sugarcane plant. **Proc. ISSCT. 17**: 438 - 445.

Gupta, S.K., K.N. Bansal and G.P.Verma.1970. Distribution of nutrient cations in saline and sodic soils of chambal command area of Madhya Pradesh. **J. Indian Soc. Soil Sci., 18**: 77-81.

Gurbakh Singh and M.Kaur.1981. Effect of growth regulators on podding and yield of mung bean (Vigna *radiata* (L.)Wilcezk). **Indian J. Plant Physiol., 24:** 366 - 370.

Gurbakh Singh, N, Sekhon and K.Manjit.1980. Effect of phenolic compounds on the yield potential of gram (*Cicer arietinum* L.). **Indian J. Plant Physiol., 23 :** 21 -25.

Halvin, J.L. and Soltanpour.1981. Evaluation of NH_4HC0_3 - DTPA soil test for iron and zinc. **Soil Sci. Soc. Am. J., 45**: 70 - 75.

Hansen, W.R. 1972. Net photosynthesis and evapotranspiration of field grown soybean canopies. **Ph.D. Thesis, Iowa University Library, America**.

Humbert, P. and J.P. Martin. 1955. Nutritional deficiency symptoms in sugarcane. **Hawaiian Plrs. Res., 55:** 95 -102.

Imsande, J. 1989. Rapid dinitrogen fixation during soybean pod filling stage enhances net photosynthetic output and seed yield. A new perspective**. Crop Sci., 29 :** 301-305.

Izaguirre-Mayoral, M.L. and T.R. Sinclair. 2005. Soybean genotypic difference in growth, nutrient accumulation and ultra structure in response to manganese and iron supply in solution culture. **Ann. Bot., 96:** 149 – 158.

Jackson, M.L. 1967. Soil chemical analysis. Asia publishing house. New Delhi. pp. 485 – 486.

Jackson, M.L. 1973. Soil chemical analysis. Prentice hall of India (P0 Ltd.., New Delhi.

Jaffe, E.K.1995. Porphobilinogen synthase, the first source of hemis asymmetry. **J. Bioenerg. Biomember., 27 :**169 -174.

Jagtap, S.M and R.B. Somavanshi.2006. Effect of soil properties and chlorosis on growth and quality of sugarcane (*Saccharum officinarum*). **Indian Sug., 56 :** 73 - 79.

Jain Radha and Shrivastava. A.K. (2003). Sugarcane International. January/ February. pp – 3 -5.

James A. Guikema. 1985. Fluorescence induction characteristics of (*Anacystis nidulans)* during recovery from iron deficiency. **J. Plant Nutr., 8** : 891- 908.

James C. Pushnik and Gene W.Miller.1989. Iron regulation of chloroplast photosynthetic function: Mediation of PS I development. **J. Plant Nutr., 12 :** 407 - 421.

Jat, J.R and R.K. Mehra.2007. Effect of sulphur and zinc on yield, macronutrient components content in uptake of mustard and Haplustepts. **J. Indian Soc. Soil Sci., 55** : 190 - 225.

Jayabal, V., Tamil Selvan, N. and Shah, S.E.1991. Effect of zinc and boron on the yield and quality of sugarcane. **Co-op. Sug., 22 :** 659 - 660.

Jing Quan Yu, LifFeng Huang, Wen Hai Hu, Yan Hong Zhou, Wei Hua Mao, Su Feng Ye and Salvador Nogus. 2004. A role of brassinosteroides in regulation of photosynthesis in (*Cucumis sativus)*. **J. Expt. Bot., 55**: 1135 - 1143.

Joshi, G.V. and G.R. Naik. 1981. Mineral nutrient balance associated with the different degrees of iron chlorosis in sugarcane var. Co 740. **Indian J. Plant Physiol., 24** : 12 - 18.

Joshi, V., M.B.Jadhav, B.R. Vaidya and P.B. Jagtap.1989. Control of calcium induced chlorosis in Adsali sugarcane. **Proc. Ann. Conv. Deccan Sug. Technol. Assoc., 39:** 398 - 399.

Juang, T.C. 1975. Nutrient balance involving Zn, Fe, Mn in sugarcane soils and fertilization in Taiwan. **Soils and Fert. Abstr**., **40 :** 585.

Juang, T.C. 1976. Trace element nutrition of sugarcane. **Taiwan Sug., 23** : 128 -139.

Junag, T.C. and T. C. Chang. 1973. Effect of Zn-Fe balance on the growth and the nutrient uptake of young sugarcane. **Taiwan Sug. Res. Inst.**, **60:** 51 - 59.

Kadam, N.A., G.A.Patil, B.A.Chaugule and S.S. Kadam.1988. Effects of foliar application of vipul on chlorophyll, active iron, catalase, peroxidase and polyphenol oxidase activities in spinach. **Indian J. Plant Physiol., 31:** 434 - 436.

Kadlag, A.D., A.B. Jadhav and S.P.Mohite.2007. Influence of zinc on yield, nutrient uptake and juice quality of adsali sugarcane on inceptisol. **Asian J. Soil Sci., 2** : 54 - 59.

Kanagaraj, T. and G. Ramanathan. 1981. Effect of different levels of CaCO3, organic residues and iron on the availability of iron and manganese. In: National Seminar on Micronutrients in Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore.

Kapur, M.L and R.S.Kanwar .1988. Yield quality and nutrient composition of sugarcane as influenced by application of micronutrients. **Proc. Ann. Conv. Sug. Technol. (India) 51:** 35 - 38.

Katyal, J.C and B.D. Sharma.1990. A new technique of plant analysis to residue iron chlorosis. **Pl. Soil., 55 :** 103 -117.

Kaur, N.P., V.K. Nayyar, and P.N. Takkar.1984. Relationship of total and ferrous iron with incidence of chlorosis in some genetic lines of (*Cicer arietinum)*. **Field Crop Res., 8:** 273 - 280.

Kelaiya, V.V., Jethwa, M.G and Patil.1991. Effect of growth regulators and their spraying schedules on groundnut. **Indian J. Agron., 36:** 111 - 112.

Khatri, S.R. and R.M. Singh. 1973. Iron and soil. **Farmers and Parliament, 8**: 22.

Kleinkopf, G.E., A. Wallace, and T. Hartsock. 1976. Lime chlorosis on photosynthesis of transpiration of iron deficient soybeans. **Comm. Soil Sci. Plt. Anal., 7:** 97 - 110.

Kudachikar, V.B., Y.C. Panchal, M.B. Chetti and P.W. Basarkar. 1992. Effects of foliar application of micronutrients on enzyme activity and quality of sugarcane grown on calcareous soil. **Ann. Plant Physiol., 6:** 92 - 97.

Kulaeva, O.N., E.A. Burkhanov, A.B. Fedeira, V.A. Knochloa, G.A. Bokebayeva, H.M. Vorbrodt and G. Adane.1991.Effect of brassinolides on protein synthesis and plant cell ultrastructure under stress conditions. In; H.G. Gutlert, T. Vok and G. Adanus (edn) Bioactivity and application. pp. 141-155. **Am. Chem. Soc.** Washington, D.C, U.S.A.

Kumar,K.C., A.S. Halepyati and B.K. Desai. Effect of organic manures and micronutrients on chlorophyll content and leaf area duration in wheat. **Indian J. Plant Physiol., 9 (1):** 98-99.

Kumaran, S. and M. Subramanian. 2001. Effect of plant population and methods of nutrient application on yield and economics of black gram. **Res. Crops., 2:** 320 - 322.

Kumaresan, K.R., Abhijit Bhattacharjee and S.P. Thirunavukkarasu, 1989. Studies on zinc nutrition of sugarcane. **Co-op Sug., 20 :** 405 - 407.

Kumaresan, K.R., Devarajan, R, P.Savithri, T.S.Manikam, and G.V. Kothandaraman. 1987. Need of micronutrients fertilization in increasing yield and quality of sugarcane. **Madras Agric. J., 74**: 372 - 376.

Kumaresan, K.R., P.P.Ramasamy and G.Ramanathan. 1988. Sugarcane needs micronutrients. Paper presented in the Sug. Cane. Res. and Dev.Workers. 17th meeting at Tamil Nadu Agricultural University, Coimbatore.

Kumaresan, K.R., P.Savithri, T.S. Manickam, G.V. Kothandaraman and Charles Daniel. 1985. Effects of applications of pressmud, $ZnSO_4$ and $FeSO_4$ on yield and quality of sugarcane**. Madras Agric. J., 72 (12):** 701 -705.

Kumavat, R.N., P.S. Rathore and H.S.Talwar.2005. Effect of sulphur and iron on growth attributes in summer green gram. **Indian J. Plant Physiol., 10**: 86-89.

Kvet, J., J.P. Ondok, J. Necas and P.G. Jarvis.1971.Methods of growth analysis. In: Plant Photosynthetic Production, Sestak, J. Catsky and P.G. Jarvis. (eds.). pp. 348 -391.

Lakshimikantham, M. 1975. The role of microelements in increasing sucrose content of sugarcane. **SISSTA Sug. Jour., 1**: 7 - 12.

Leidi, E.O., M. Gomez and M.D.de La Guardia 1986. Evaluation of catalase and peroxidase as indicators of Fe and Mn nutrition for soybean. **J. Plant Nutr., 10** : 261 - 271.

Linder, R.C. and C.P. Harley. 1944. Nutrient interrelationships of lime induced chlorosis. **Plant Physiol., 19:** 420 - 439.

Lowry, A.H., N.T.Rose Brough, L.A Fait and R.J. Randall.1951. Protein measurement with folin phenol reagent. **J. Biol. Chem., 19 :** 262 - 275.

Lucena, J.J., A. Garate, A.M. Ramon and M. Manzanares.1990. Iron nutrition of hydronic strawberry culture (Frgaria vesca L.) supplied with iron chelates. **Pl. Soil. 123 :** 9 - 15.

MacNicol, P.K., M.L. Dudzinski and B.N. Condon. 1976. Estimation of chlorophyll in tobacco leaves by direct photometry. **Ann. Bot., 40 :** 143 - 152.

Mani, S. and K.Mayalagu.1986. Effect of combined application of phosphorus and iron on available phosphorus in soil with Paddy crop. **Andhra Agric. J., 33:** 326 -329.

Marinho, M.L., and G.A.C. Albuquarque.1981.Effect of copper and zinc on the production of sugarcane on table land soils of Alagoas. **Brazil A Cu. 98** : 437-447. (Portugese) ISJ 85: pp. 111-118.

Marsh, H. V., H. J. Evans and G. Martrone. 1963. Investigation on the role of iron in chlorophyll metabolism. 1. Effect of iron deficiency on chlorophyll and

heme content and on the activities of certain enzymes in leaves. **Plant Physiol., 38 :** 632 - 638.

Mathur, B.S.1975. Effect of micronutrients on sugarcane and its quality. **Indian Sug., 25 :** 179 - 181.

Mathur, S.K. and N.R. Talati. 1984. Note on the iron chlorosis in sugarcane leaves and its corrective measures. **Curr. Agric., 8**: 103 -105.

Meade, G.P and J.C.P. Chen.1977. Cane sugar Hand Book 10th Ed., John Willey and Sons Inc., New York.

Mehrotra, S.C, Preeti Gupta, Kalpana Chatruvedi and S.S. Bisht. 1990. Active iron in relation to chlorophyll and activities of some Fe-enzymes in maize. **Ind. J. Exp. Bot., 28 :** 349 - 351.

Mengal, K., M. Th. Breomomger and W. Biibl. 1984. Bicarbonate, the most important factor inducing iron chlorosis in vine grapes and calcareous soil. **Pl. Soil., 81:** 333 - 344.

Miller, G.W., A. Denney, J.Pushnik and M.H.Yu.1982. The formation of delta aminolevulinate: a precursor of chlorophyll in barley and role of iron. **J. Plant Nutri., 5:** 289 - 300.

Minolta.1989. SPAD- 502.Owners Industrial meter Div. Minolta Crop. Ramsay, N.J. Lu and Zhang.

Mishra, S.G. and Pande. 1974. Evaluation of a suitable extractant for available iron in soils. **Indian. J. Agric., Sci**., **44**: 865 - 870.

Mohamed Amanullah, M., A. Alagesan, S. Pazhinivelan and K.Vaiyapuri.2007. Effect of iron on metabolically active iron and chlorophyll in sole and intercropped sorghum. **Crop Res., 33**: 62 - 64.

Mohan Rao, N.V., C. Rama Rao and G. Narasimha Rao. 1956. Preliminary studies on the effect of micronutrients on sugarcane. **Indian Sug., 6** : 73 - 76.

Morales, F., A. Abadia, R. Belkhodja and J.Abadia.1994. Iron deficiency induced changes in the photosynthetic pigment composition of field grown pear (*Pyrus communalis* L) leaves. **Plant Cell Environ., 17 :** 1153 - 1160.

Muralidharadu, Y. and M. Singh. 1990. Effect of iron and zinc application on yield, oil content and nutrient uptake by sesame. **J. Indian Soc. Soil Sci., 38**: 171 - 173.

Naemet, A.A., Abd EL-Gawad, Nour El-Din, I.H. EL-Geddawi and N.B. Azazy.1992. Effect of nitrogen and zinc on growth criteria of sugarcane plants.
P.S.J. VI: 3 -10.

Naidu, K.M., S. Ramakrishan and K.V. Bhagyalakshmi. 1980. Causative factors for the occurrence of chlorosis in sugarcane grown in red loamy soils. **Proc. ISSCT, 17 :** 732 - 739.

Naik, G.R. and G.V. Joshi.1974. Photosynthetic carbon fixation in iron chlorotic and recovered green sugarcane leaves. **Pl. Soil., 53 :** 505 - 511.

Narinder P. Kaur., P.N. Takkar and V.K. Nayyar. 1984. Catalase, peroxidase and chlorophyll relationships to yield and iron deficiency chlorosis in Cicer genotypes. **J. Plant Nutr.,7 :** 1213 - 1220.

Nawalgatte, C.M. and Y.C. Panchal. 1991. Effect of different levels of growth regulators on growth and yield of groundnut. **J. Maharashtra Agric. Univ., 6** : 122 - 123.

Nayyar, V.K., S.P. Singh, and P.N. Takkar. 1984. Response of sugarcane to zinc and iron sources. **J. Res. Punjab Agric. Univ., 21**: 134 - 136.

Nenova, V and L.Stoyanav.1993. Physiological and biochemical changes in young maize plants under iron deficiency I. Growth and photosynthesis. **J. Plant Nutri., 16** : 835 - 849.

Odurukwe, S.O. and D.N. Maynard. 1969. Mechanism of differential response of Wf 9 and OH 40 B corn seedlings to iron nutrition. **Agron. J., 61:** 694 - 697.

Olsen, S.R. and C.W. Carlson. 1950. Iron chlorosis of sorghum and peas as related to extractable soil iron and manganese. **Soil Sci. Soc.Am.Proc**. **14**: 109 - 112.

Olsen, S.R.., C.V.Cole., F.S. Watanabe and LA. Dean.1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. **U.S.D.A. Cir. No.939**.

Oserkowsky, J. 1933. Quantitative relationship between chlorophyll and iron in green and chlorotic leaves. **Plant Physiol., 8:** 449 - 468.

Pal, A.R., D.P.Motiramani, S.B.Gupta and B.S.Bhargava.1990. Chlorosis in sugarcane;associated soil properties, leaf mineral composition and crop response to iron and manganese. **Fert. Res., 22:** 129 - 136.

Palanivel, A. 1990. Effect of soil and foliar applied iron on sugarcane in calcareous soil. **Indian Sug., 40** : 117.

Palliwal, K.V and T.R. Subramanian. 1964. Possible relationship of CEC of plant roots to cation uptake. **Curr. Sci., 33 :** 463.

Pandya, D.H., R.K. Mer, P.K. Prajith and A.N. Pandey.2004. Effect of salt stress and manganese on growth of barley seedlings**. J. Plant Nutr**., **27**: 1361 - 1379.

Parthasarthy, S.V.1980. Research on micronutrients in sugarcane. **Sugdev. Technical Services Sorayur (India).** pp 55 - 61.

Patel, G.J., B.U. Ramakrishnaya and B.K. Patel. 1977. Effect of soil and foliar application of ferrous sulphate and of acidulation of soil on iron chlorosis of paddy seedlings in Goradu soils, Nuca series in India. **Pl. Soil., 46** : 209 - 219.

Patel, H.S., N.J. Mehta, M.P. Patel and P.D. Vekariya. 1991. Impact of various micronutrients and growth regulators on yield and quality of sugarcane (var Co C 671) in presence of recommended practices of fertilization under south Gujarat conditions. **Indian Sug.**,**40 :** 825 - 826.

Patil, S.V., S.R. Patil and H.R. Arakeri. 1956. Further studies on iron deficiency chlorosis in sugarcane. **Proc. Ann. Conv. Deccan Sug. Technol. Assoc., 13** : 43.

Pearce, R.B, R.H.Brown and R.E. Balaster.1968. Photosynthesis of alfalfa leaves as influenced by environment. **Crop Sci., 36:** 677 - 680.

Perur, M.G.1962. Measurement of peroxidase activity in plant tissue. **Curr. Sci., 31**: 17 -18.

Piper, C.S. 1966. Soil and plant analysis. Interscience publishers Inc., New York.

Polle, A., K. Chakrabarti, K. Chakrabart, S, Sufert, F, Scharamel, P, and H. Rennerberg. 1992. Antioxidants and Mn deficiency in needles of Norway spruce trees. **Plant Physiol., 99 :** 1084 - 1089.

Prakash, M., S.Suganthi, J.Gokulakrishnan and T. Sabesan. 2007. Effect of 28-Homobbrassinolide on morphophysiological and yield parameters of Sesame. **Indian J. Plant Physiol., 12** : 91 - 94.

Prince, C.A. 1968. Iron compounds and plant nutrition. **Ann. Rev. Plant Physiol., 19:** 239 - 248.

Rahman, M.H., A. Choudhury and A. Hossain. 1986. Effect of micronutrients on yield and sucrose content of sugarcane in calcareous and non-calcareous soils of Bangladesh. **Proc. Intern. Sym. Dhaka, Bangladesh, 12:** 254 - 280.

Rajagopal, C.K., K.K.Krishnamoorthy and M.Moosa Sherif.1975. Micronutrient status of Tamilnadu soils. **SISSTA Sug. J., 1** : 1 - 6.

Rakkiayappan, P.1993. Efficacy of certain micronutrient formulation on sugarcane. Ann. Report. 1992-1993. Sugarcane Breeding Institute, Coimbatore, India.

Rakkiyappan, P and S. Thangavelu. 2000. Effect of Iron on ratoon crop of six sugarcane varieties grown in iron deficient soil. International conference on managing natural resources for sustainable Agricultural production in the 21st century. February 14-18, 2000. New Delhi, India Vol. II : 266 - 268.

Rakkiyappan, P. 1987. Effect of soil types and levels of nitrogen and potassium on yield, quality and nutrient uptake of two sugarcane varieties (CoC 671 and Co 6304). **Ph.D. Thesis submitted to Tamil Nadu Agricultural University, Coimbatore.**

Rakkiyappan, P.1986. Survey of micronutrient status of sugarcane growing tracts in tracts in relation to different varieties. **Ann. Rep., 1986**. Sugarcane Breeding Institute, Coimbatore.

Ramadass,R. and R. Devarajan. 1991. Critical level of iron in soils of Coimbatore district. **Madras Agric. J., 78 :** 254 - 255.

Ramanathan, G., N. Nagasundaram, D. Augustine Selvaseelan and A. Bhaskar. 1987. Prediction of iron chlorosis in sugarcane from plant analysis. **Madras Agric. J.,** 74**:** 89 - 93.

Ranferi Maldonado-Torres, Jorge Dionisio Etchevers-Barra, Gabriel Alcantar-Gonzalez, Jorge Rodriguez-Alcazar, and Maria Teresa Colinas-Leon. 2006.

Morphological Changes in Leaves of Mexican Lime Affected by Iron chlorosis. **J. Plant Nutr., 29** : 615–628.

Rao, N.P. 1989.Suitability of plant nutrient in sugarcane. **SISSTA Sug. J**., 15 : 41-52.

Rao, P.N and R.L. Narasimham.1990. Effect of root CEC on dry mater production, yield (grain/seed) nitrogen content and its uptake by some varieties of legume and cereal crops. **The Andhra agric. J. 37:** 1 - 4.

Rao, R.S and K.V.Rao.1988. Studies on macro and micronutrient composition of certain soils and plants and ratoon cane crops raised on the same Pithapuram factory area of APO. **Bharatiya Sug., 13:** 45 - 48.

Rao, S.1978. Guidelines for use of micronutrients in sugarcane. **Sug. J., 15:** 41 - 52.

Reddi Ramu, Y and D.S. Reddy. 2007. Effect of micronutrients on growth, yield, quality and economics of hybrid maize. **Crop Res., 31**: 46 - 49.

Reddy, S.M., P.N. Rao and C. Shivalingam. 1985. Micronutrient content of sugarcane in Nizamsagar Ayacut area of Andhra Pradesh. **Maharashtra Sug., 10:** 17-23.

Reyes, J.M., M.C. del Campillo and J. Torrent. 2006. Soil Properties Influencing Iron Chlorosis in Grapevines Grown in the Montilla- Moriles Area, Southern Spain. **Communications in Soil Science and Plant Analysis, 37:** 1723-1729.

Rombala, A.D., Y. Gorgorcena, A. Larbi, F. Morales, E. Baldi, B. Marangoni, M. Tagliavini and J.Abadia. 2005. Iron deficiency-induced changes in carbon fixation and leaf elemental composition of sugar beet (*Beta vulgaris*) plants. **Pl. Soil., 271 :** 39 - 45.

Sairam, R.K.1994. Effect of homobrassinolide application on metabolic activity and grain yield of wheat under normal and water stress conditions. **J. Agr. Crop Sci., 173 :** 11 - 16.

Sangwan, B.S and K.Singh.1993. Vertical distribution of Zn, Mn, Cu and Fe in the semi-arid soils of Haryana and their relationship with soil properties. **J. Indian Soc. Soil Sci., 41:** 463 - 467.

Schemhl, W.R. and R.P. Humbert. 1964. Nutrient deficiencies in sugar crops. In: H.B.Sprague (Ed.). Hunger Sign in crops. David McKay Co., New York. pp. 415 -450.

Seethambaram, Y and V.S.R. Das.1985. Photosynthesis and activities of C_3 and C_4 photosynthesis enzymes and zinc deficiencies in (*Ozyza sativa)* and (*Penisatum americanum)*. **Soil Fertl., 48**: 108 - 149.

Sen, A. and A. Samad. 1975. Periodic variation in micronutrient status of soil and plant – A study in relation to sugarcane growth in North Bihar calcareous soils. **J. Indian Soc. Soil Sci., 23 :** 495 - 499.

Sen, A., J. Prasad and C.R. Prasad.1985. Studies on the soil application of micronutrients in sugarcane to plant micronutrient balance, yield and commercial cane sugar. **Proc. Ann. Conv. Sug. Technol. Assoc., 48:** 69 - 75.

Sharma, B.L., A.K. Mishra, R.R. Singh and S.B. Singh.2002. Micronutrient fertilization in sugarcane: Effects of zinc and boron in calcareous soil. **Indian Sug., 52** : 439 -443.

Sharma, K.P. and R.S.Kanwar. 1985. Effect of micronutrient on some biochemical activities of high sucrose variety of sugarcane in calcareous soil. **Trop. Agric., 62 :** 334 - 338.

Sharma, S.C. and G.S.C. Rao. 1978. Critical level assessment and physiological roles of trace elements in sugarcane – A review. **Indian Sug., 28** : 551-555.

Shigeoka, S., T. Ishikawa, M. Tamoi, Y. Miyagawa, T. Takeda, Y. Yabuta and K. Yoshimura. 2002. Regulation and function of ascorbate peroxidase isoenzymes. **J. Exp. Bot., 53 :** 1305 - 1319.

Shinde, A.G., D.N. Magadum, V.D.Patil, and J.R. Patil. 1986. Response of seasonal sugarcane to soil application of zinc sulphate in Kolhapur region. **Proc. 35th Ann. Conv. D.S.T.A**..: A.155 -158.

Shive, J.W. 1941. Significant role of trace elements in nutrients of plant. **Pl. Physiol., 16:** 435 - 445.

Shrivastava., A.K. D.V. Yadav, C.Chatterjeee, B.K. Dube, R.C. Pant, I.M. Chhibba, Munn Singh, Alok Shukla, P.N. Singh, Radha Jain and Manoj.K. Srivastava. 2004. In "Chlorosis in Sugarcane"**.** Indian Institute of Sugarcane Research, Luknow, India pp – 45.

Shyamananda Patnaik. 1950. The effect of manganese on catalase activity of rice plant. **Pl. Soil., 11** : 418 - 419.

Singh, K.D.N., A.P.Singh and U.S. Prasad.2000. Effect of different modes of zinc application on yield and quality of sugarcane in calciorthents. **J. Indian Soc. Soil Sci., 48:** 624 - 626.

Singh, R.G. 1972. The microelement nutrition of sugarcane. **Co-op. Sug., 4** : 5-12.

Singh, R.G., H. P. Verma and J. P. Singh. 1974. Effect of micronutrients on growth, yield and juice quality of sugarcane. **Proc. STAI Conv., 40:** 81 - 89.

Singh, R.P. and P.P. Singh. 1973. Effect of micronutrients on the performance of sugarcane. **Indian J. Agron., 18**: 124 - 136.

Singh, S and L.C. Ram.1973. CEC of roots of different varieties of wheat crop and its relation to available nutrients, pH and electrical conductivity. **J. Indian Soc. Soil Sci., 21:** 367 - 371.

Singh, U.S. 1973. Iron chlorosis - A devasting disease of sugarcane. **Indian Sug., 23:** 755 - 756.

Singh, U.S. and Lallan Singh. 1973. Investigations on sugarcane chlorosis in Uttar Pradesh. IV. Influence of iron, manganese and nitrogen applied as foliar spray on growth, yield and quality of chlorosis affected crop. **Indian Sug., 23 :** 525 - 528.

Singh,S.P and Dwivedi, D.K. 2007. Impact of zinc, boron and iron elements on yield components and economics of ginger. **Internat. J. Agric. Sci., 3:** 136 - 138.

Skoog, F.1940. Relationship between zinc and auxin in the growth of higher plants. **Amer. J. Bot., 27**: 939 - 951.

Somavanshi, R.B and P.P.Kadu.1988. Effects of soil properties on growth and chlorosis in sugarcane. **J. Plant Nutri., 11** : 1545 -1555.

Somers, I. I. and T. M. Shive. 1942. The iron-manganese relation in plant metabolism. **Plant Physiol., 17 :** 525 - 534.

Soundarajan, R. 1984. Maximising iron availability in calcareous soil. M.Sc (Ag.) dissertation submitted to and approved by the Tamil Nadu Agricultural University, Coimbatore.

Srinivas, D., B.R. Mukunda Rao, V. Ramulu, K. Obulpathi and M.Vijayakumar.2001. Effect of micronutrients on the yield and quality of sugarcane variety 83 R 23. **Proc. SISSTA. 26:** 53 - 56.

Srivastava, S.C., M.Tewari and D.K.Tandon.1978. Ameliorating lime induced chlorosis of cane with pyrite. Paper presented at the Seminar On “Use of sedimentary pyrites as reclamation of Alkali soils” held in Luknow, India.

Stanford, S.and L. English. 1949. Use of flame photometer in rapid soil test of K and Ca. **Agron. J., 41 :** 446 - 447.

Subbiah, B.V and G.L .Asija .1956.A rapid procedure for estimation of available nitrogen in soils. **Curr. Sci., 25 :** 259 - 260.

Swarup, A.1984. Effect of micronutrients and farmyard manure on the yield and micronutrient content of rice and wheat grown on sodic soil. **J. Indian Soc. Soil Sci., 32** : 397 - 399.

Takkar, P.N. and N.P. Kaur. 1983. HCl method for Fe^{2+} estimation to resolve iron chlorosis in plants. 2nd International symposium on iron nutrition and interaction in plants. August 2-5, 1983, Logan, Utah, U.S.A.

Tamilmani, S. 1983. Fixation of critical limit for iron in calcareous soils of Coimbatore district using sorghum variety Co24. **M.Sc (Ag.) thesis submitted to Tamil Nadu Agricultural University, Coimbatore.**

Tandon, D.K. and S.C. Srivastava. 1978. Simulating lime induced chlorosis in sugarcane. **Indian J. Sug. Cane Technol., 1:** 107 - 114.

Tandon, D.K. and S.C. Srivastava. 1981. Characterizing lime induced chlorosis of sugarcane. **J. Indian Soc. Soil Sci., 29:** 343 - 348.

Tandon, D.K. and S.C. Srivastava. 1981. Total and available forms of distribution of iron in some Sierozem soils of Haryana. **J. Indian Soc. Soil Sci., 29**: 132-133.

Terry, N. 1984. Limiting factors in photosynthesis: iron stress mediated changes in light-harvesting and electron transport capacity and its effects on photosynthesis in vivo. **Plant Physiol., 71** : 855 - 860.

Terry, N. and G. Low.1982. Leaf chlorophyll content and its relation to the intercellular localization of iron. **J. Plant Nutr., 5** : 301 - 310.

Terry, N. and J. Abadia. 1986. Function of iron in chloroplasts. **J. Plant Nutr., 9**: 609 -646.

Theoder Keller and Werner Koch. 2005. The effect of iron chelate fertilization of poplar upon CO_2 – uptake, leaf size, and content of leaf pigments and iron. **Pl. Soil. 1O (1):** 116 -126.

Tomar, P.S., O.P.Mathur and D.S.Oberai.1965. Iron deficiency in ratoon crop of sugarcane in canal irrigated soils of Rajasthan. **Indian Sug., 9:**123.

Tonapy, C.K. 1965. Preliminary studies with trace elements. **Proc. 20th Ann. Conv. Deccan Sugar Tech. Assoc. (India)**. pp. 205 - 207.

Tong Yue Ao, R.L. Chaney, R.F. Korcak, F.Fan and M. Faust.1987. Influence of soil moisture level on apple iron chlorosis development in calcareous soil. **Pl. Soil. 104 :** 85 - 92.

Trierweiller, J.F. and W.L.Lindsay. 1969. EDTA – ammonium carbonate oil test for zinc. **Soil Sci. Am.Proc., 33 :** 49 - 54.

Tripathy, H.C., R.S. Singh and V.K.Mishra. 1999. Effect of S and Zn nutrition on yield and quality of chickpea. **J. Indian Soc. Soil Sci., 45**: 123 -126.

Umadevi, T.K.1998. Studies on the physiological basis of partitioning and its regulation for maximizing yield in sesame (*Sesamum indicum* L) **M.Sc (Ag.) Thesis, submitted to Tamil Nadu Agricultural University, Coimbatore.**

Van Dillevijn, 1952. Botany of sugarcane. The chronica Co., Valtham MASS, U.S.A, pp. 111.

Vardhini, V.B and S.S.R. Rao.1998. Effect of brassinolides on growth, metabolite content and yield of (*Arachis hypogea)*. **Phytochemistry, 48:** 927 - 930.

Vassilios Chouliaras, Loannis Therios, Athanassious Molassiotis, Angelos Patakas and Gregorious Diamantidis. 2004. Effect of iron deficiency on gas exchange

and catalase and peroxidase activity in citrus. **J. Plant Nutr., 27 (12) :** 2085 - 2099**.**

Velu, G. 1989a. Soil factors including chlorosis in sugarcane. **Res. and Dev. Reporter, 6:** 161 - 163.

Velu, V. 1977. Studies on the effect of application of calcium and iron to groundnut (*Arachis hypogaea*). **M.Sc. (Ag.) dissertation submitted to the Tamil Nadu Agricultural University, Coimbatore.**

Venkatasubramanyam, A. and B.H. Mehta. 1975. Effect of Zn, Fe and moisture on the availability of Zn, Fe and Mn in soil. **J. Indian Soc. Soil Sci**., **23:** 236 - 241.

Wallace, A. and R.T. Muller. 1980. Effect of nitrogen rates on iron nutrition chlorosis in P 154619-5-1 soybean. **J. Plant Nutri., 2** : 199 - 201.

Wallace, A., G.A.Wallace and J.W. Cha. 1992. Some modifications in trace metals toxicities and deficiencies in plants resulting from interaction with other elements and chelating agents- the special case of iron. **J. Plant Nutri., 15** : 1589 - 1598.

Wang, J.J., C.W. Kennedy, H.P. Viator, A.E. Arceneaux, and A.J. Guidry. 2005. Zinc fertilization of sugarcane in acid and calcareous soils. **J. Amer. Soc. Sug. Cane Technol., 23:** 49 - 61.

Warden, B.T. and R.S. Reinsenwear. 1991. Manganese – iron interaction in the plant soil system. **J. Plant Nutri., 14**: 7 - 30.

Waritch, K.S and R.S. Kanwar. 1988. Amelioration of sugarcane chlorosis by nutrient elements and their effect on cane yield. **Proc. Ann. Conv. Sug. Technol. Assoc. (India). 51** : 47 - 52.

Watson, D.J. 1958. The dependence of net assimilation rate on leaf area index. **Ann. Bot., 58 :** 37 - 54.

Watson, D.J.1956. Comparative physiological studies on the growth of field crops. I. Variation in net assimilation rate and leaf area between species and varieties and with in and between years. **Ann. Bot., 2 :** 41- 46.

Wetblank, P.J., S.A.W. French and J.K. Wittis.1966. Dependence of yield of wheat varieties on their leaf area duration. **Ann. Bot., 30:** 291 - 299.

Williams, S.R.F. 1946. Methods of growth analysis. In: Plant Photosynthetic Production Manual and Methods, Sestak, Z., J. Catasky and P.J. Jouris (eds.) Drow, Jenk, N.U. Publishers, The Hague. pp. 348 - 391.

Woods, M.J. and C.G. Nolan. 1968. Effect of phosphorus and iron on tomatoes. **Irish J. Agric. Res., 7** : 201 - 207.

Yadav, D.V and N.P.S.Yadduvanshi.1989. Micronutrients for increasing sugarcane production. **Indian Sug., 39 :** 225 - 227.

Yadav, D.V. and K. Singh. 1988. Lime-induced iron chlorosis in sugarcane. **Fert. Res., 16 :** 119 - 136.

Yadav, D.V., and T. Singh and K. Singh. 1987. Response of sugarcane to foliar application of micronutrients. **Indian Sug. Cane Technol., 4:** 42 - 46.

Yadav, P.S. (1998). Response of mungbean to varying levels of P and Fe on loamy sand soil. M.Sc Thesis, Rajasthan Agricultural University, Bikaner.

Yadava, A.K., T.P. Yadava and B.D. Choudhary. 1979. Path coefficient analysis of the association of physiological traits with grain yield and harvest index. **Indian J. Agric.Sci., 49:** 89-90.

Yerriswamy, R.M., N. Vasuki and T. Satyanarayana. 1994. Alleviation of iron chlorosis of maize on calcareous vertisols. **J. Indian Soc. Soil Sci., 42**: 156 - 159.

Yoshida, S.D., A. Foron and J.H. Cock. 1971. Laboratory methods for Physiological studies of Rice. IRRI, Philippines. pp. 36 – 37.

Zekri, M. and L.R. Parsons.1990. Response of split-root sour orange seedlings to NaCl and polyethylene glycol stresses. **J. Exp. Bot., 41:** 35 - 40.

Zende, C.K. 1979. Effect of micronutrients on yield and quality of sugarcane – Soil status and deficiency symptoms. In "A review of research on micronutrients in sugarcane" (Ed., Parthasarathy, S. V.). Sugadev Technical Services Pub., Sorayur: 1-50.

Zende, C.K. and M.M. Kibe. 1977. Cane quality in relation to levels of Mn added to soil ranging in chemical fertility. **SISSTA Sug. J., 3:** 41 - 56.

Zende, G.K. 1968. Studies on the effect of manganese on cane yield and quality. **J**. **Indian Soc. Soil Sci., 16**: 315 - 322.

Fig. 5 Total chlorophyll content as influenced by the chosen treatments (Trial I)

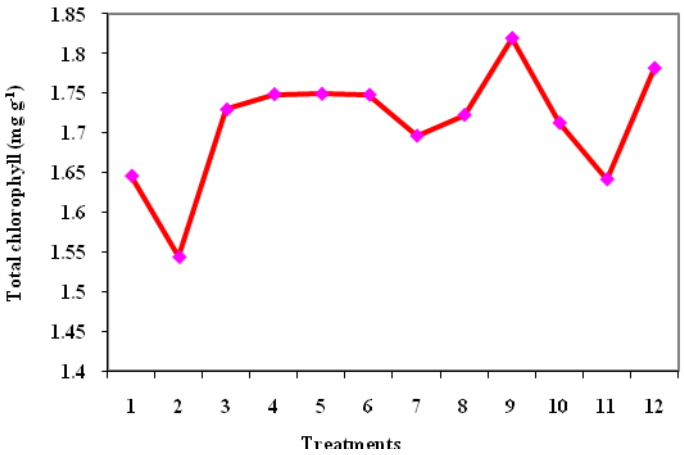


Fig. 11 Soluble protein content as influenced by the chosen treatments (Trial I)

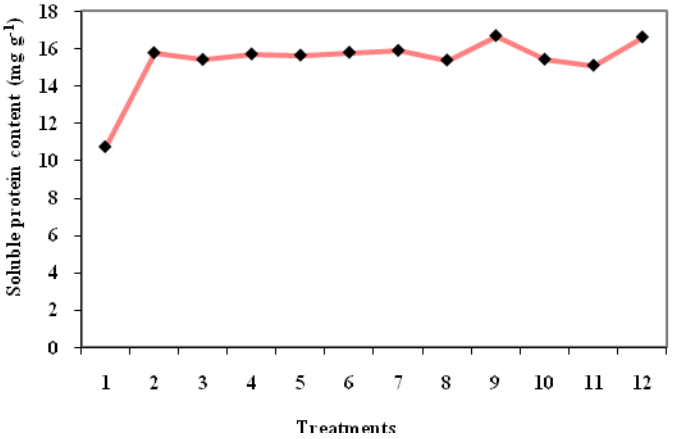


Fig. 21 Fe/Mn ratio in root as influenced by the chosen treatments (Trial I)

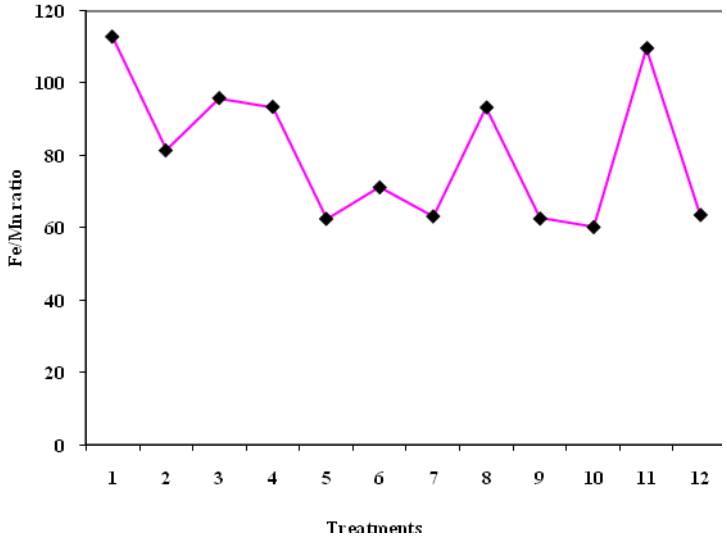


Fig. 17 SOD activity as influenced by the chosen treatments (Trial I)

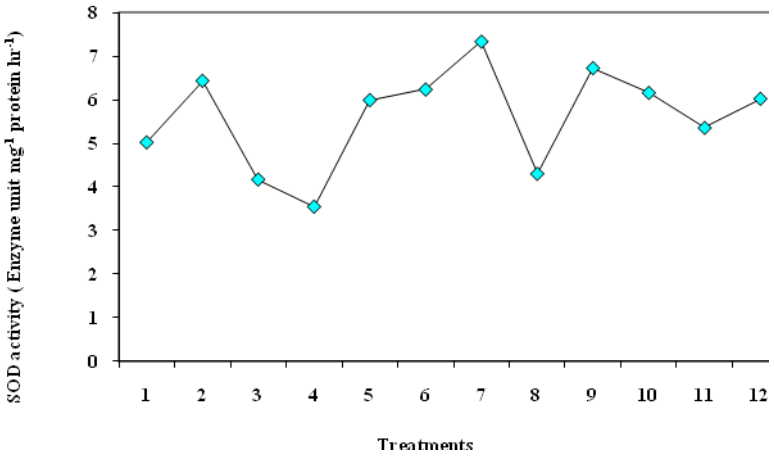


Fig. 25 Number of millable cane as influenced by the chosen treatments at harvest (Trial I)

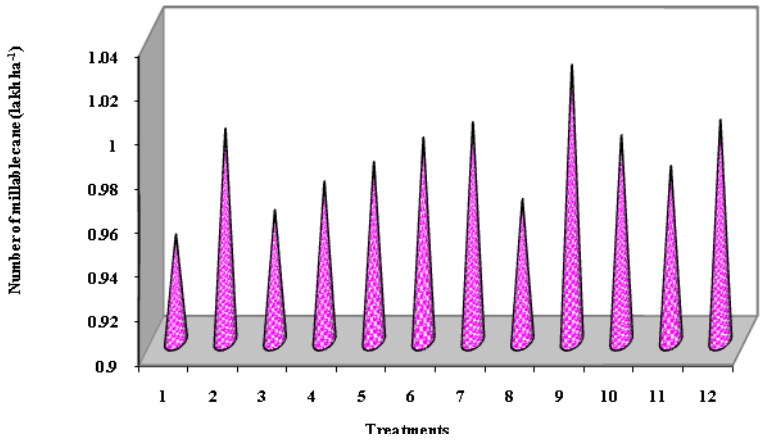


Fig. 27 Millable cane height as influenced by the chosen treatments at harvest (Trial I)

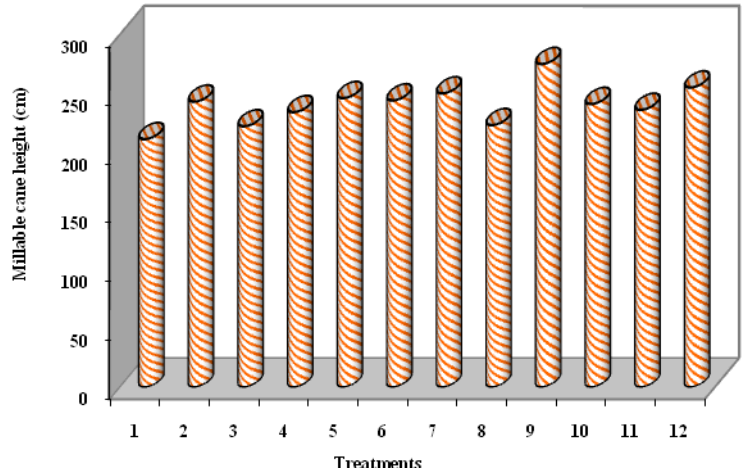


Fig. 35 Brix (%) of the cane juice as influenced by the chosen treatments at harvest (Trial I)

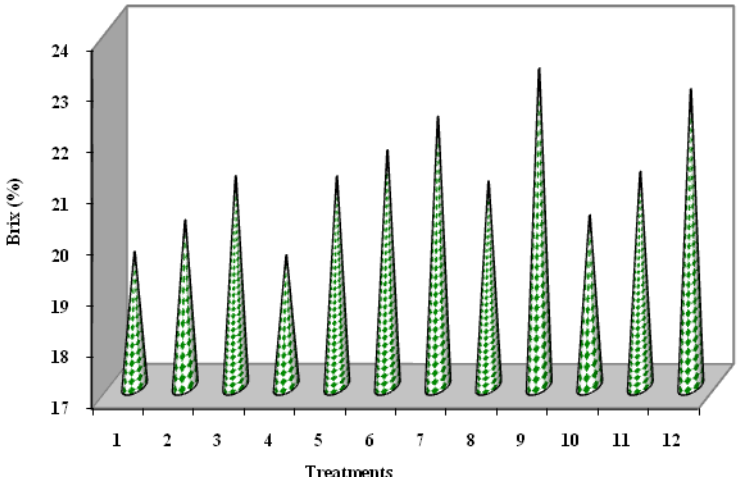


Fig 8. SPAD values as influenced by the chosen treatments (Trial II)

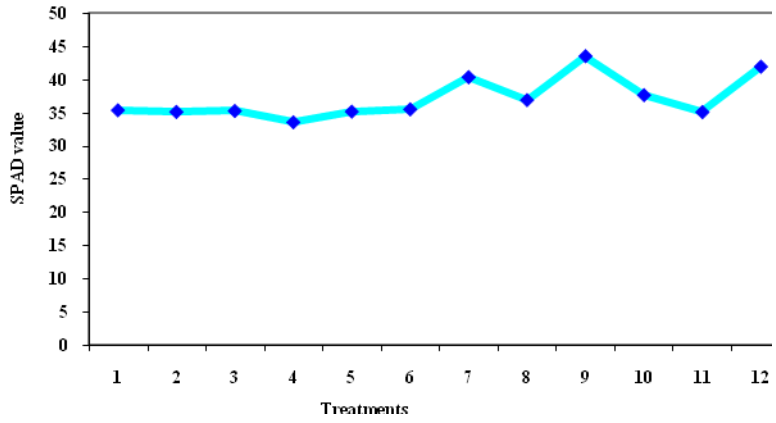


Fig. 29 Number of internodes as influenced by the chosen treatments at harvest (Trial I)

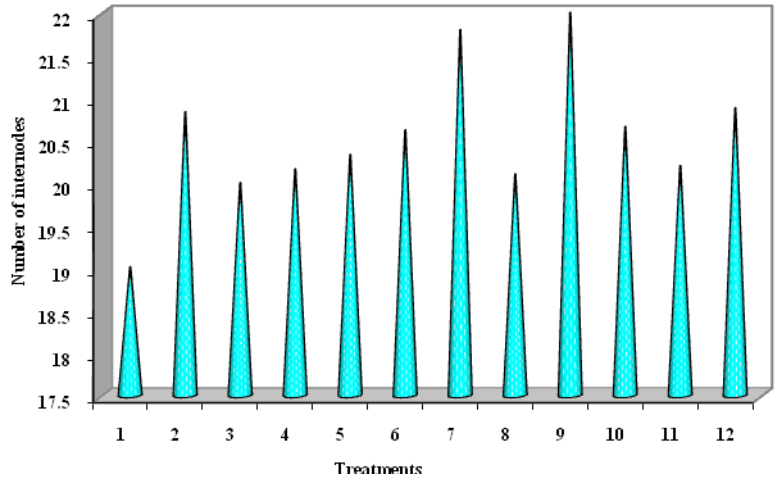


Fig. 41 Cane yield as influenced by the chosen treatments (Trial I)

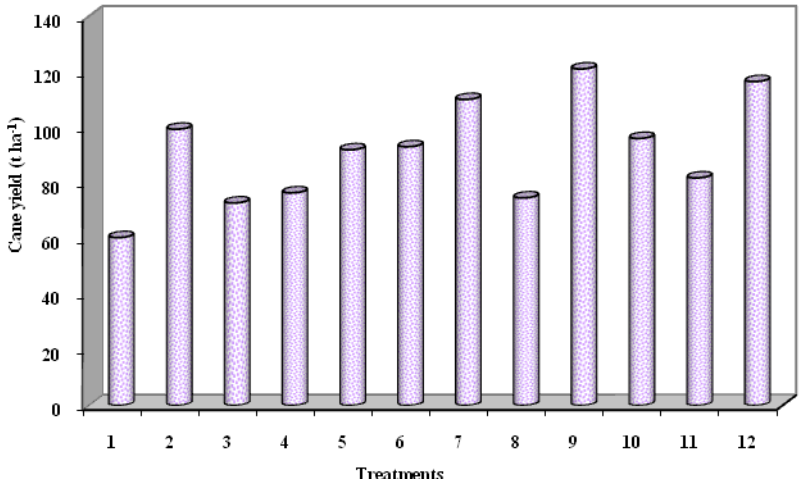


Fig. 19 Metabolic active iron as influenced by the chosen treatments (Trial I)

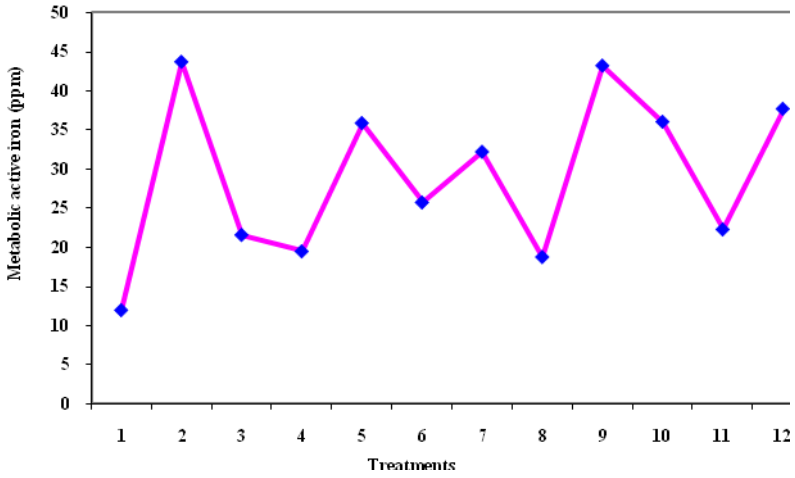


Fig. 15 Catalase activity as influenced by the chosen treatments (Trial I)

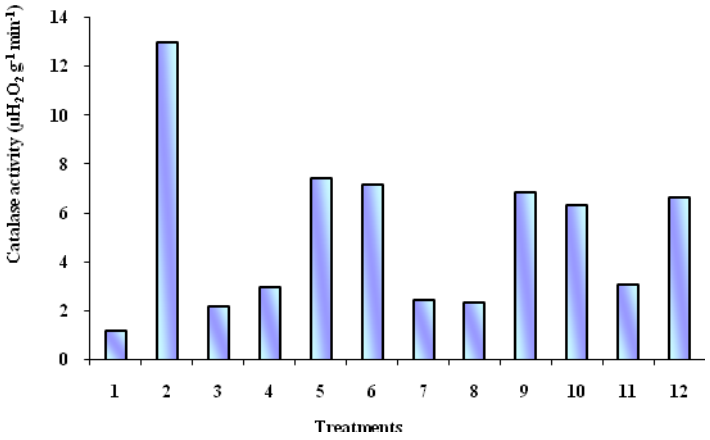


Fig. 13 Cation exchange capacity as influenced by the chosen treatments(Trial I)

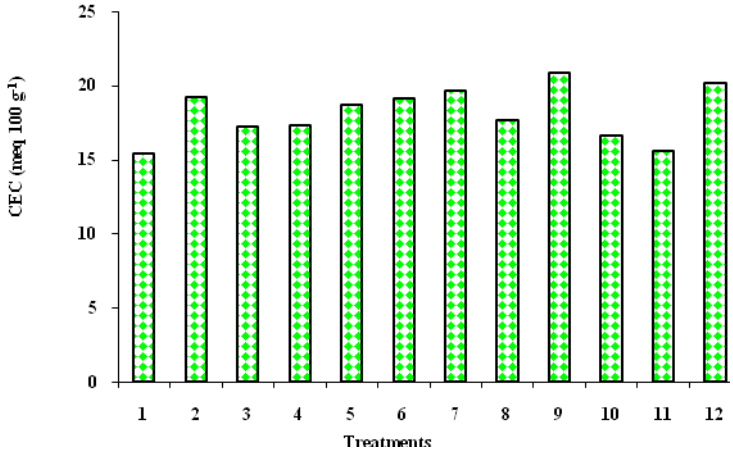


Fig. 23. P/Fe ratio in root as influenced by the chosen treatments (Trial I)

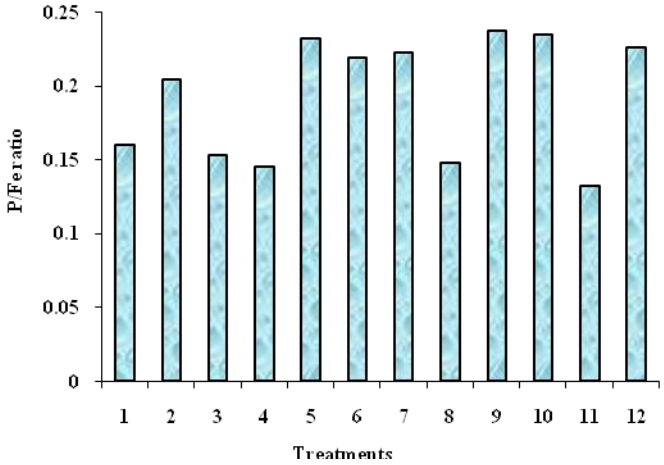


Fig 3. Tillering capacity as influenced by the chosen treatments at 100 DAP (Trial I)

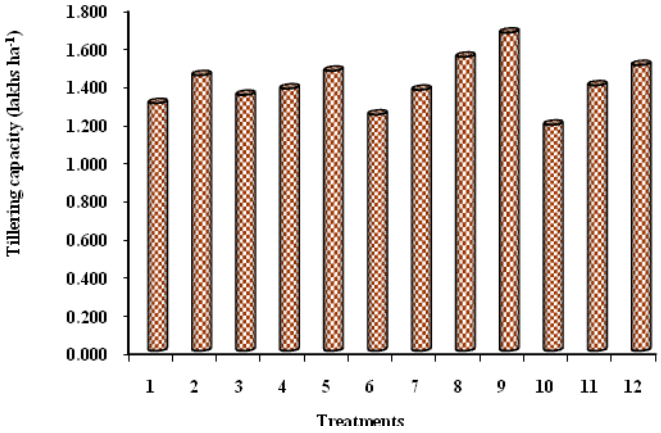


Fig. 33 Millable cane weight as influenced by the chosen treatments at harvest (Trial I)

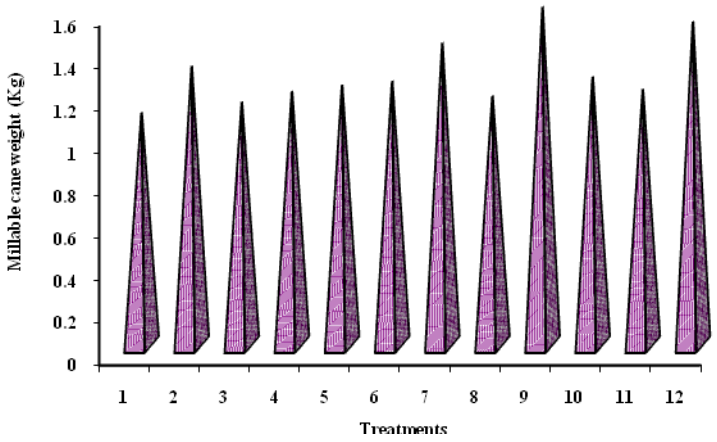


Fig. 36 Pol (%) in cane juice as influenced by the chosen treatments (Trial I)

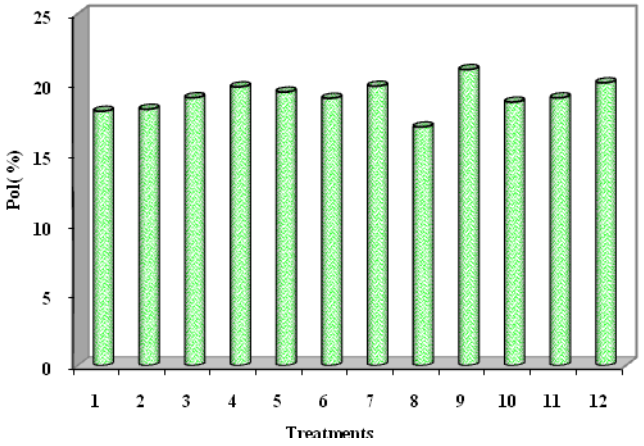


Fig 10. Photosystem II efficiency (Fv/Fm) ratio as influenced by the chosen treatments(Trial II)

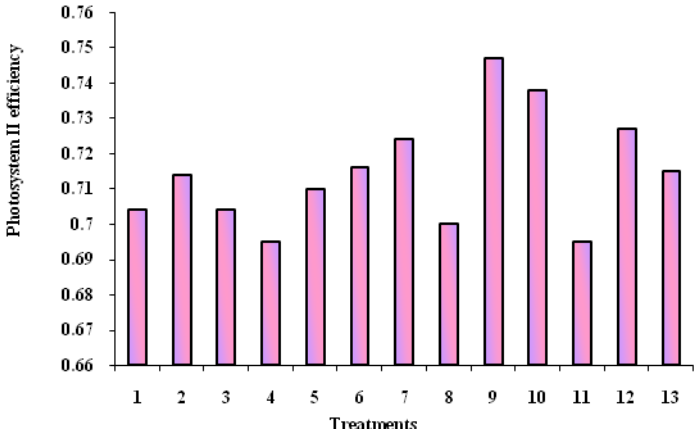


Fig. 31 Cane girth as influenced by the chosen treatments at harvest (Trial I)

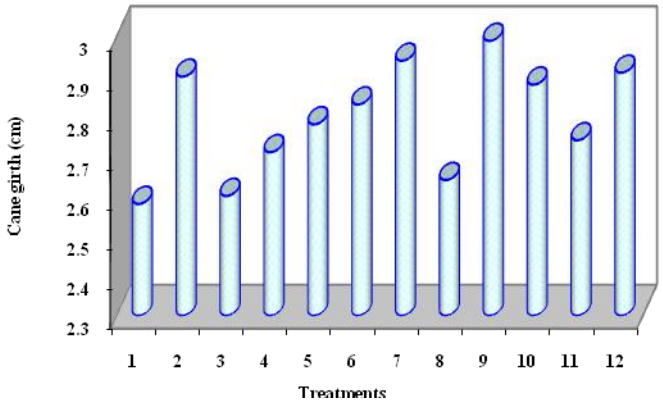


Fig. 37 Commercial cane sugar (%) as influenced by the chosen treatments at harvest (Trial I)

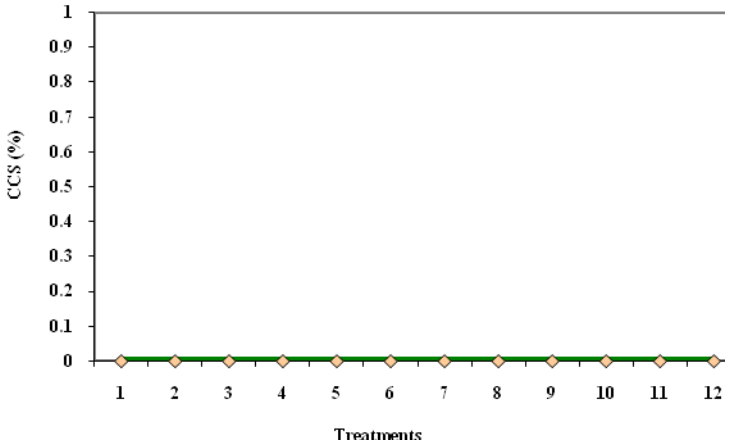


Fig. 43 Sugar yield as influenced by the chosen treatments (Trial I)

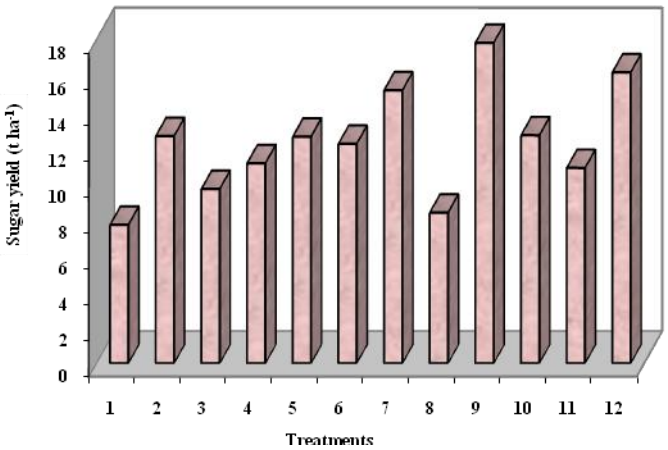


Fig 6. Total chlorophyll content as influenced by the choosen treatments (Trial II)

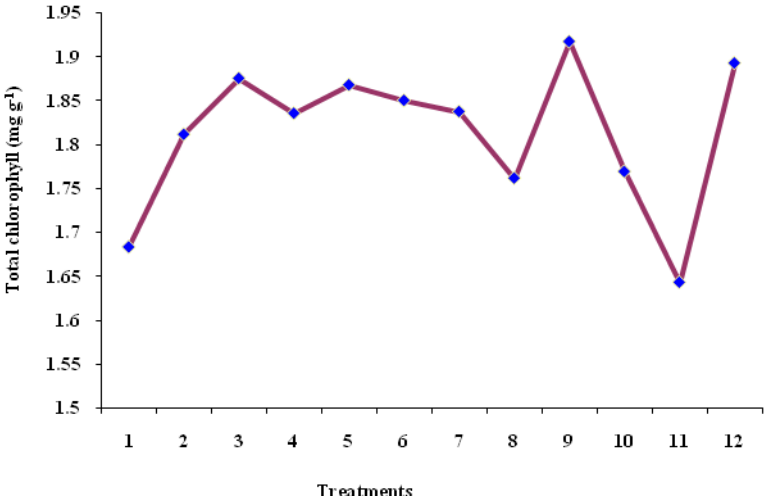


Fig 12. Soluble protein content as influenced by the choosen treatments(Trial II)

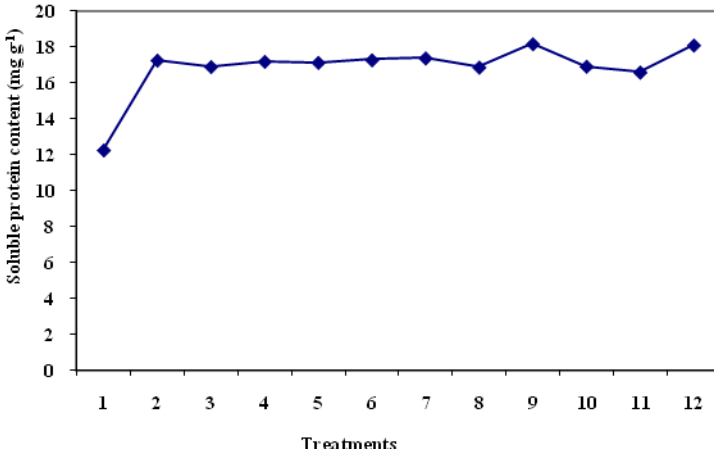


Fig. 22 Fe/Mn ratio in root as influenced the by choosen treatments(Trial II)

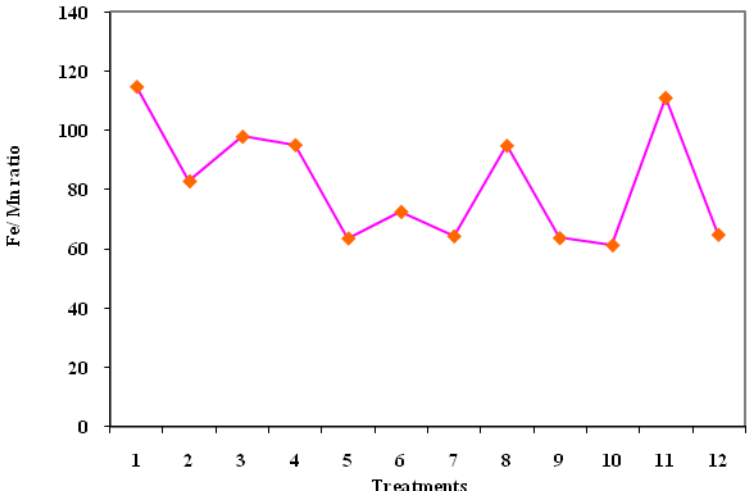


Fig. 18 SOD activity as influenced by the choosen treatments (Trial II)

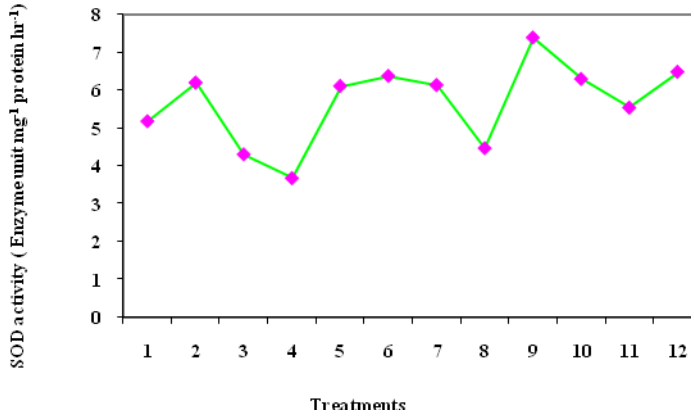


Fig. 26 Number of millable cane as influenced by chosen treatments at harvest (Trial II)

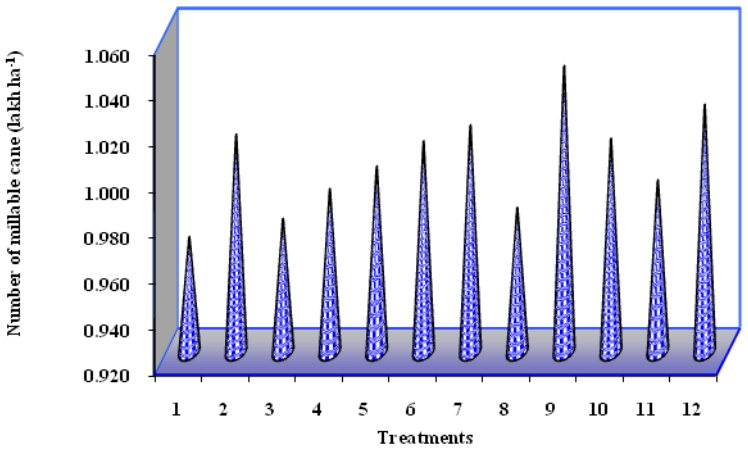


Fig. 28 Millable cane height (cm) as influenced by the chosen treatments at harvest (Trial II)

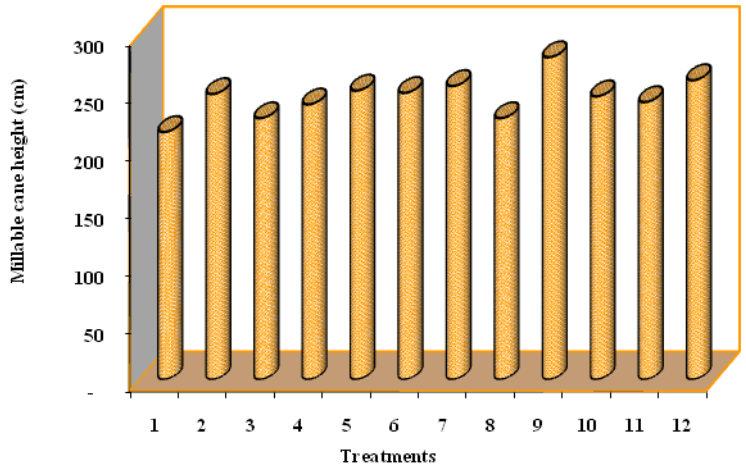


Fig 38. Brix (%) of the cane juice as influenced by the chosen treatments at harvest (Trial II)

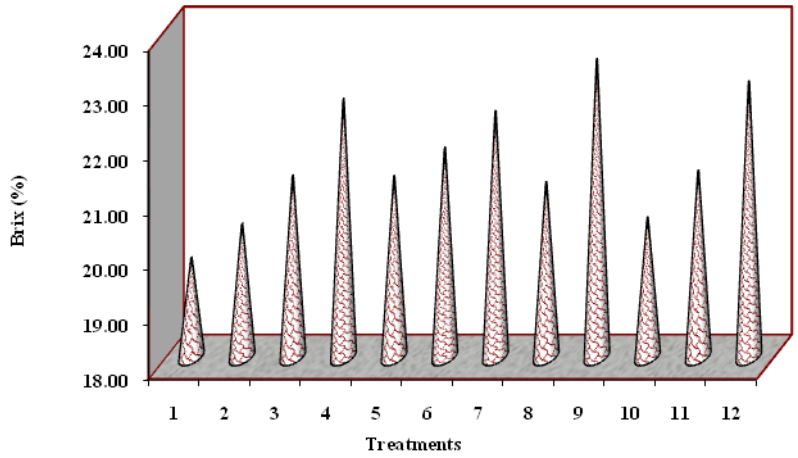


Fig 7. SPAD values as influenced by the chosen treatments (Trial I)

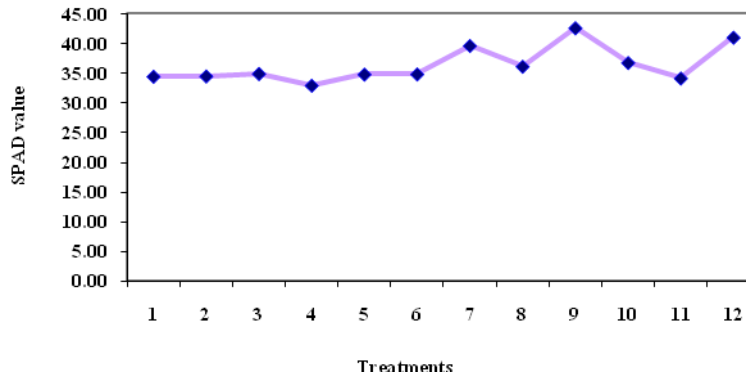


Fig. 30 Number of internodes as influenced by the chosen treatments at harvest (Trial II)

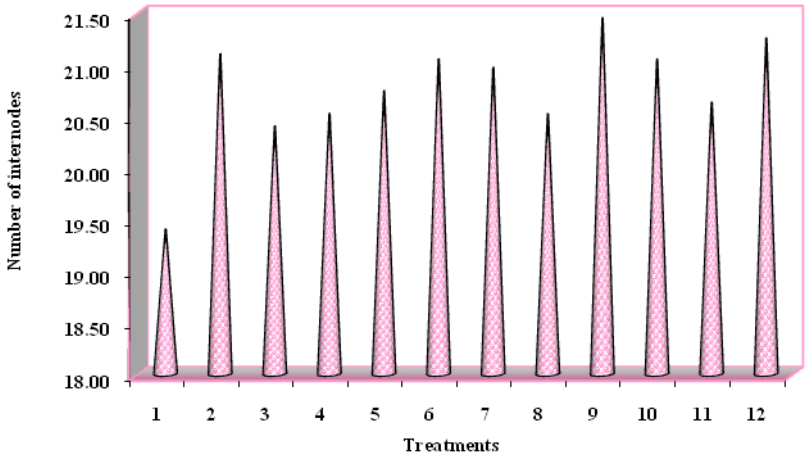


Fig. 42 Cane yield as influenced by the chosen treatments (Trial II)

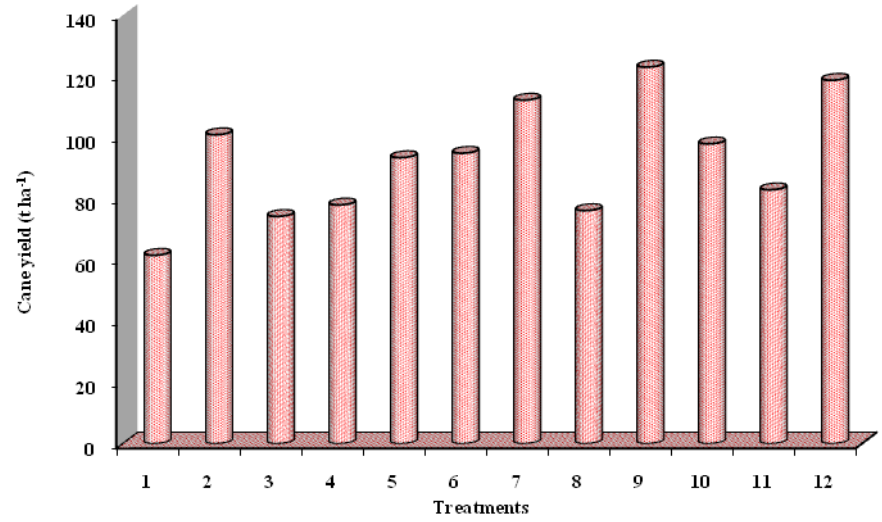


Fig. 20 Metabolically active iron as influenced by thechosen treatments (Trial II)

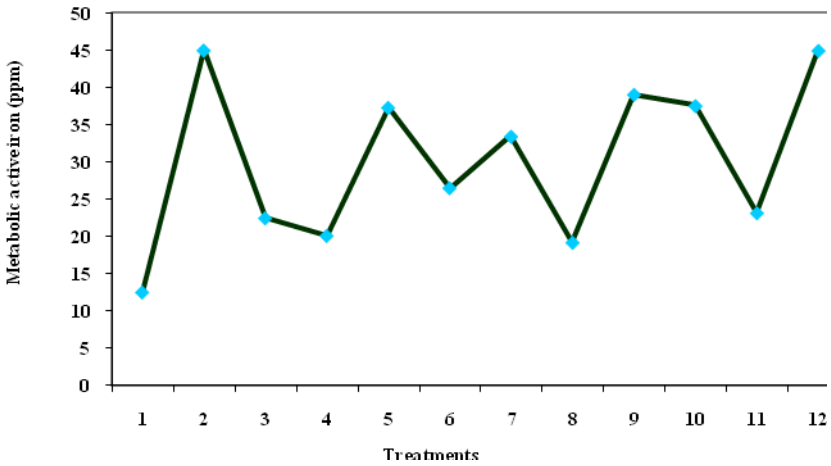


Fig. 16 Catalase activity as influenced by the choosen treatments (Trial II)

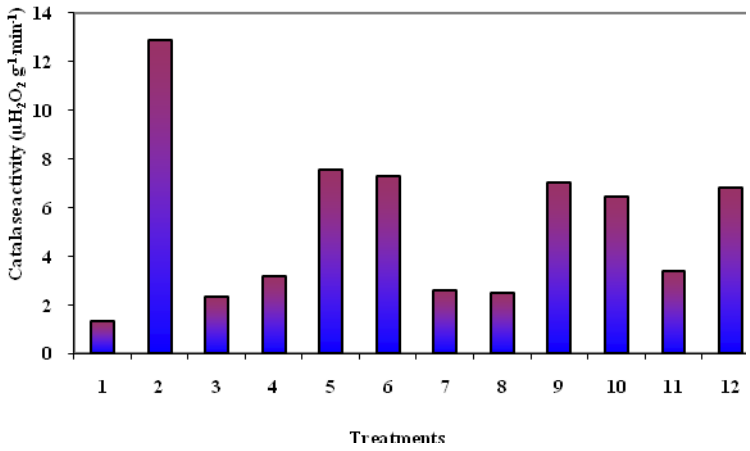


Fig.14 Cation exchange capacity as influenced by the choosen treatments (Trial II)

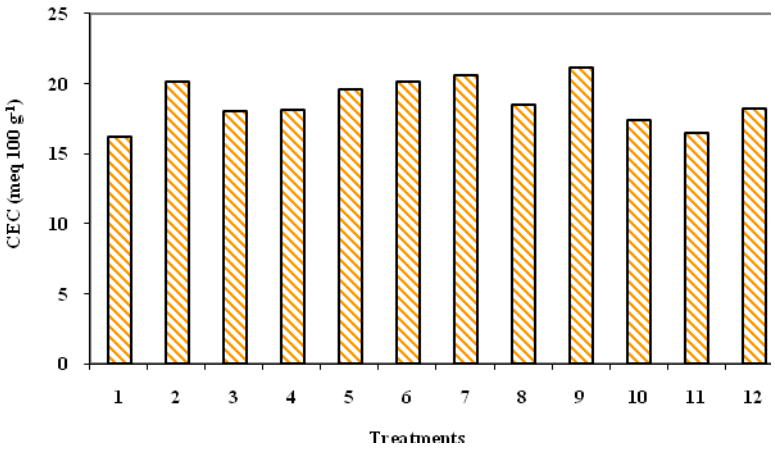


Fig. 24 P/Fe ratio in root as influenced by the choosen treatments (Trial II)

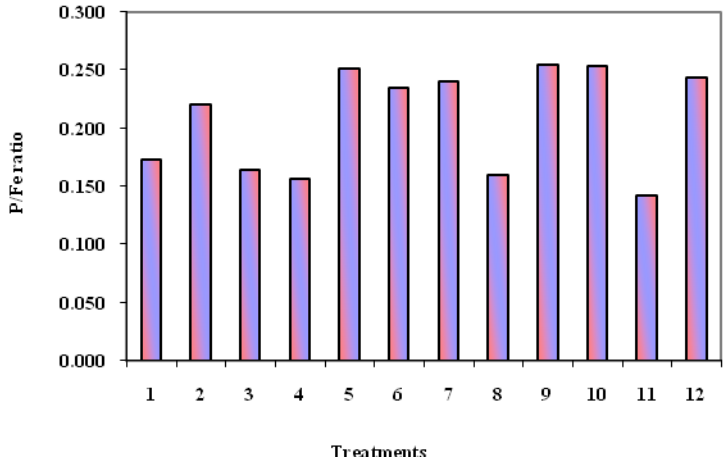


Fig 4. Tillering capacity as influenced by the chosen treatments 100 DAP

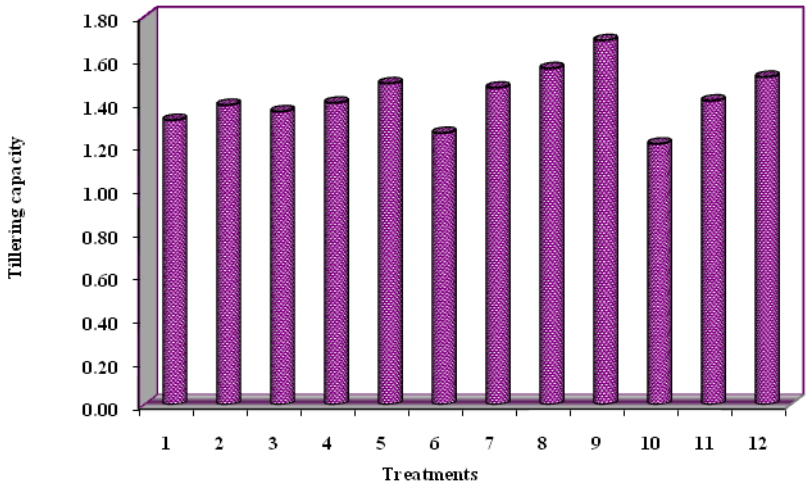


Fig. 34 Millable cane weight as influenced by the chosen treatments at harvest (Trial II)

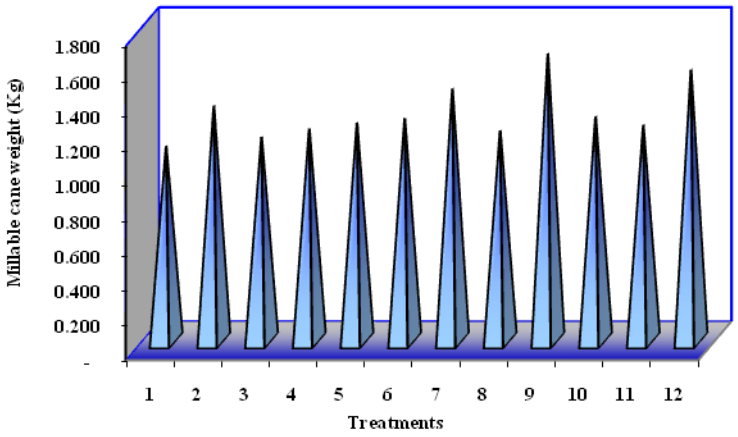


Fig.39 Pol (%) in cane juice as influenced by the chosen treatments (Trial II)

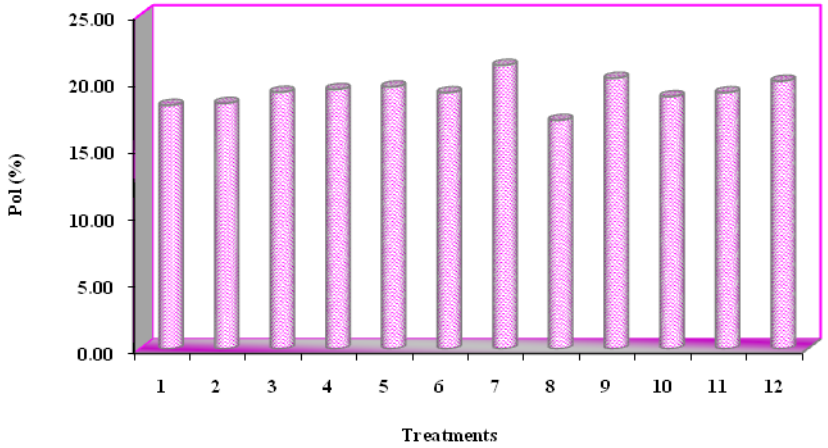


Fig 9. Photosystem II efficiency (Fv/Fm) ratio as influenced by the chosen treatments (Trial I)

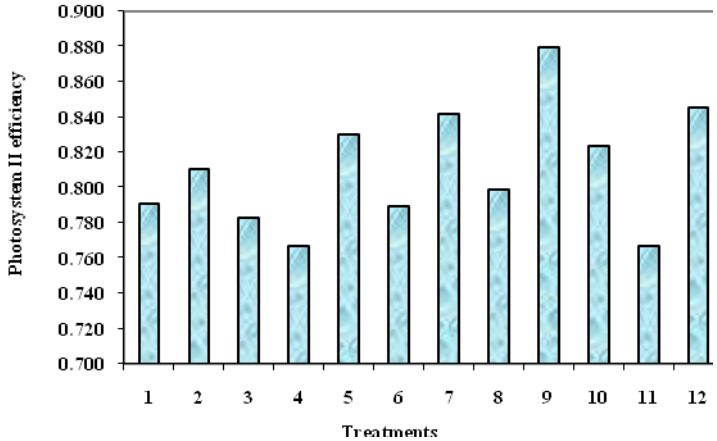


Fig 32. Cane girth as influenced by the chosen treatments at harvest (Trial II)

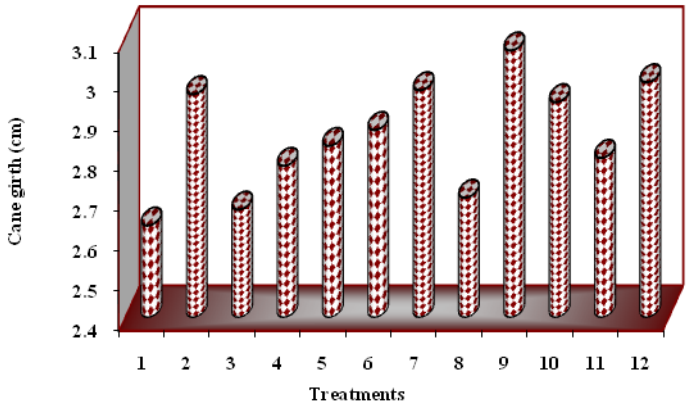


Fig. 40 Commercial cane sugar (CCS %) as influenced by the chosen treatments at harvest (Trial II)

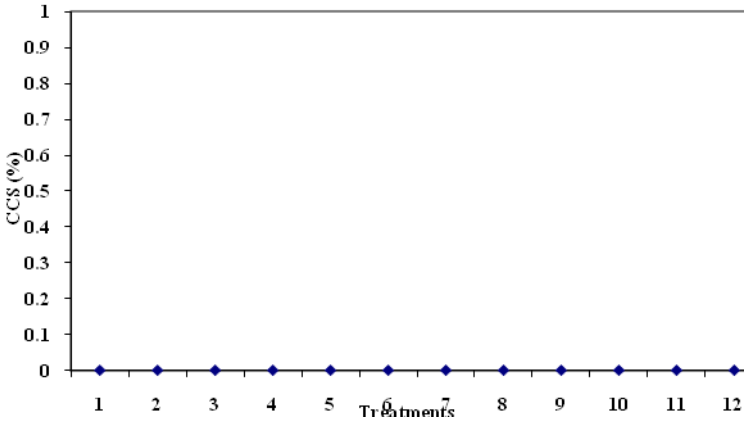
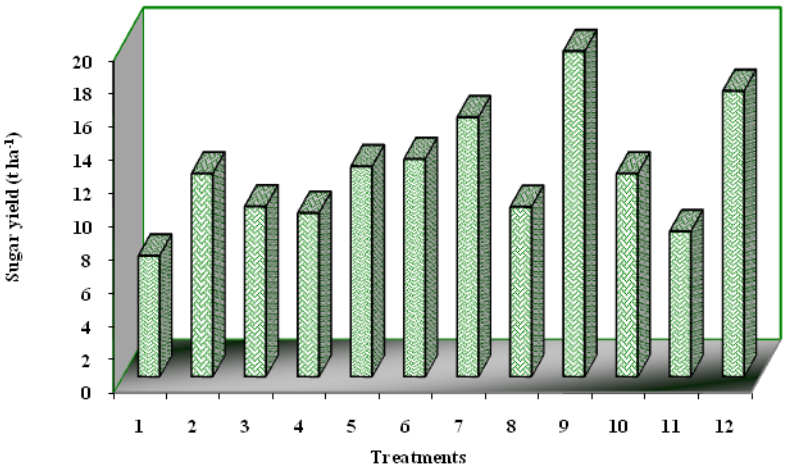
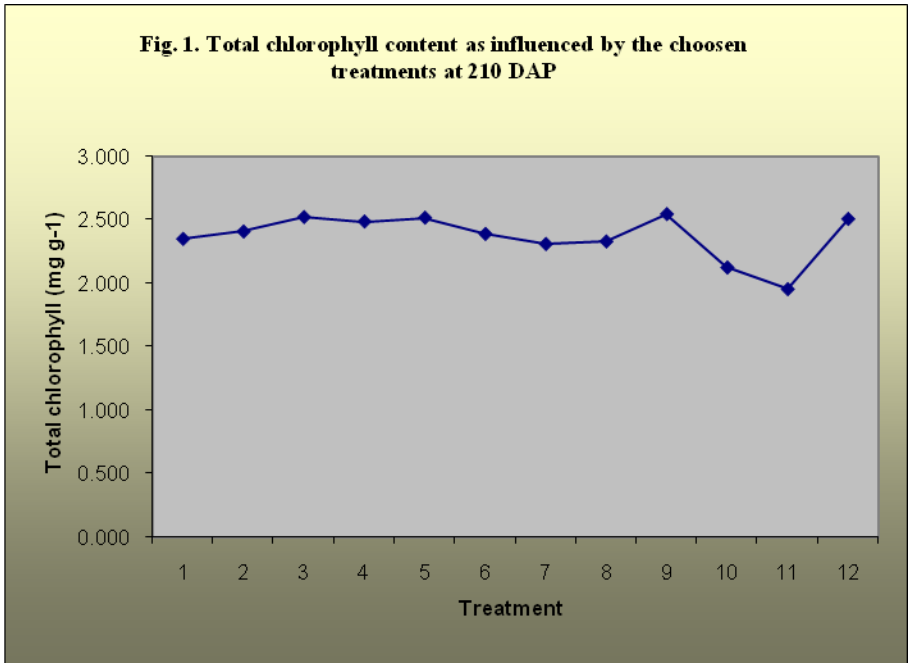


Fig.44 Sugar yield as influenced by the chosen treatments (Trial II)





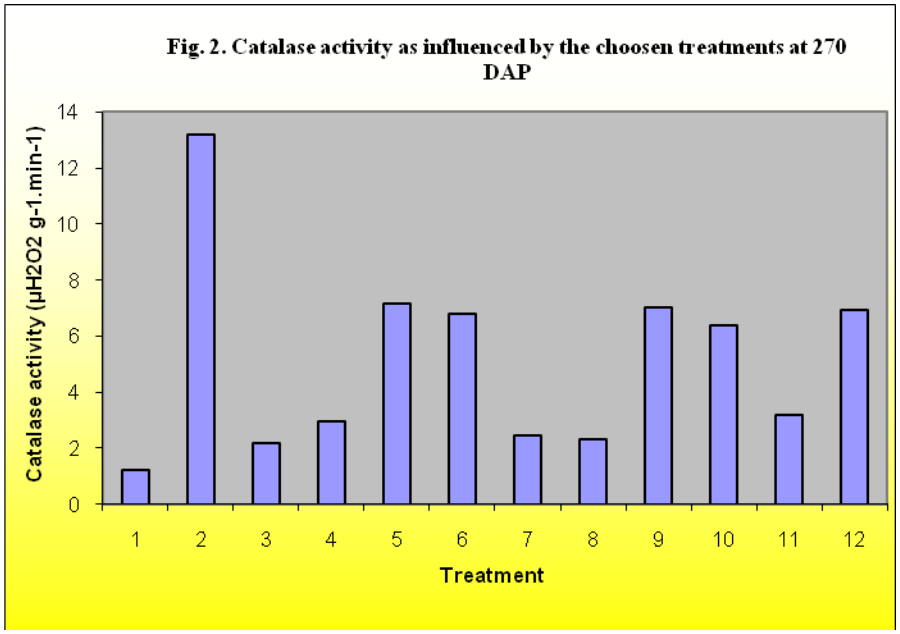


Fig. 2. Catalase activity as influenced by the choosen treatments at 270 DAP
Catalase activity (µH2O2 g-1.min-1)
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
8
9
10
11
12
Treatment

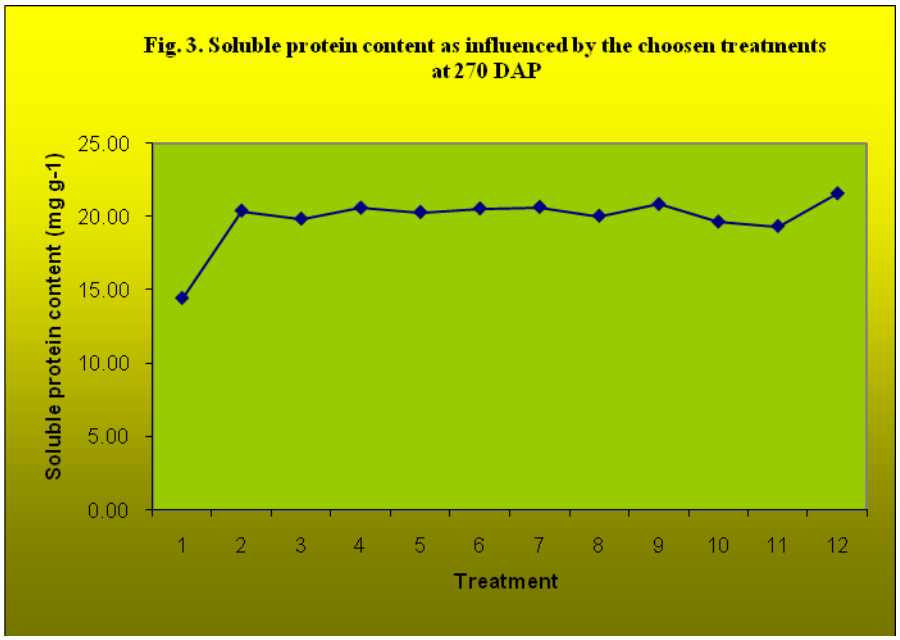


Fig. 3. Soluble protein content as influenced by the choosen treatments at 270 DAP
Soluble protein content (mg g-1)
0.00
5.00
10.00
15.00
20.00
25.00
1
2
3
4
5
6
7
8
9
10
11
12
Treatment

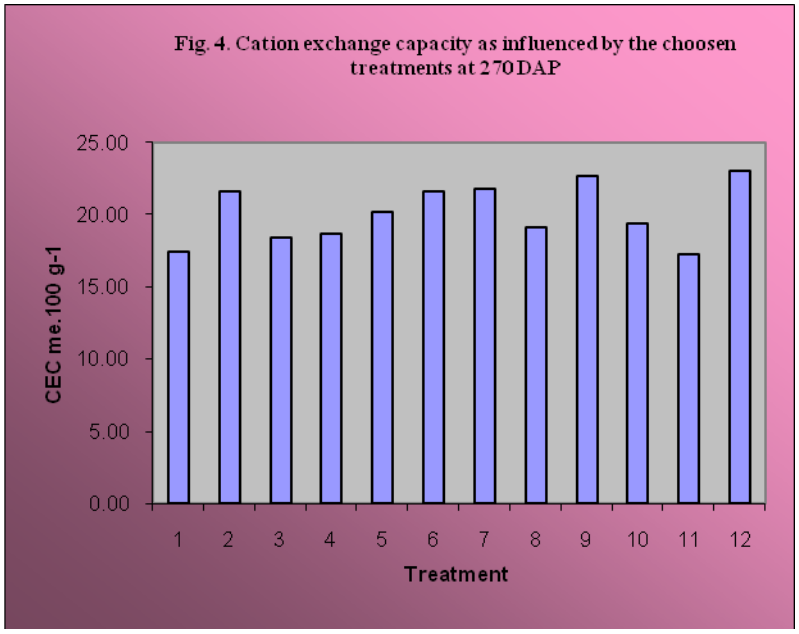


Fig. 4. Cation exchange capacity as influenced by the choosen treatments at 270 DAP
CEC me.100 g-1
25.00
20.00
15.00
10.00
5.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12
Treatment

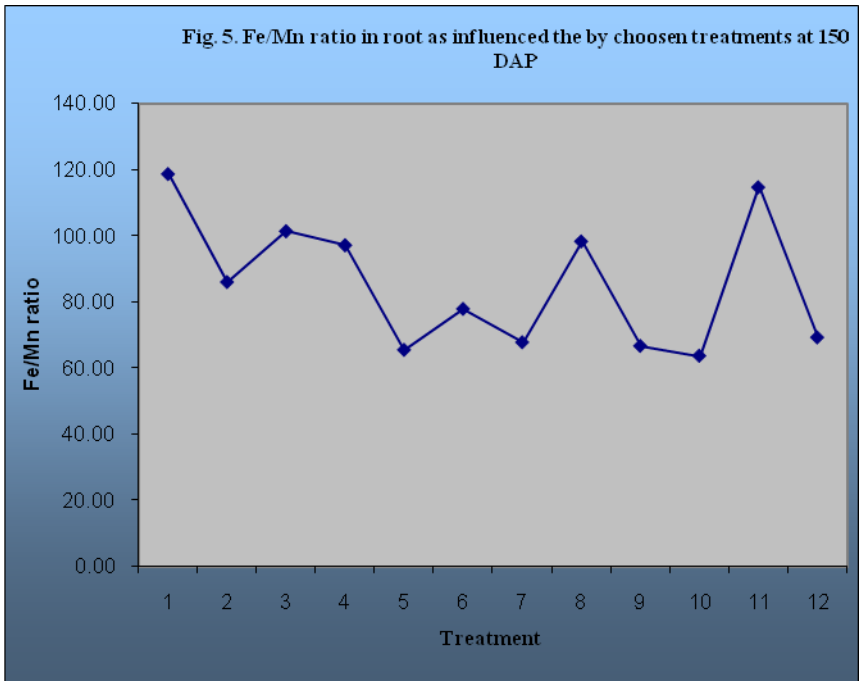


Fig. 5. Fe/Mn ratio in root as influenced the by choosen treatments at 150 DAP
Fe/Mn ratio
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12
Treatment

Fig. 6. P/Fe ratio in root as influenced by the choosen treatments at 270 DAP

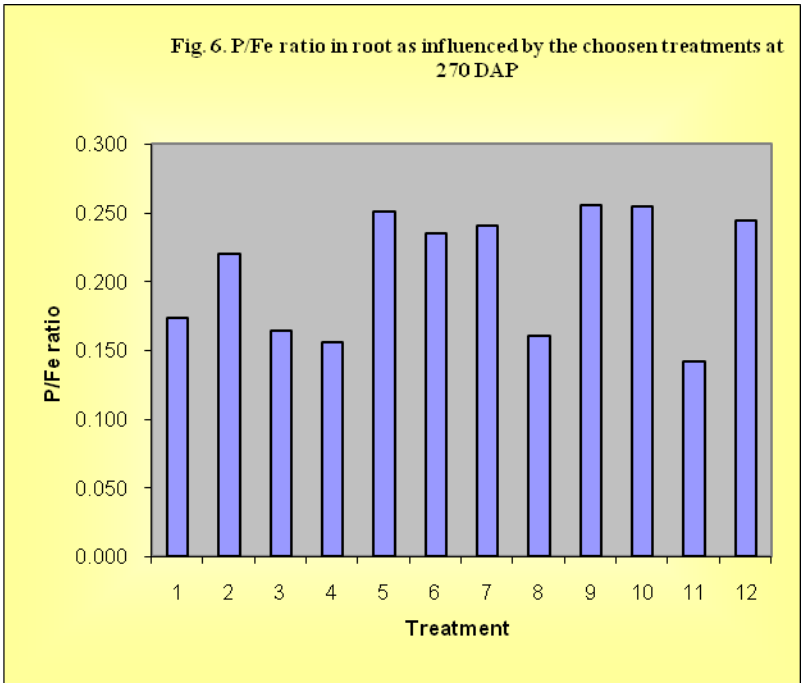


Fig. 7. SOD activity as influenced by the choosen treatment at 210 DAP

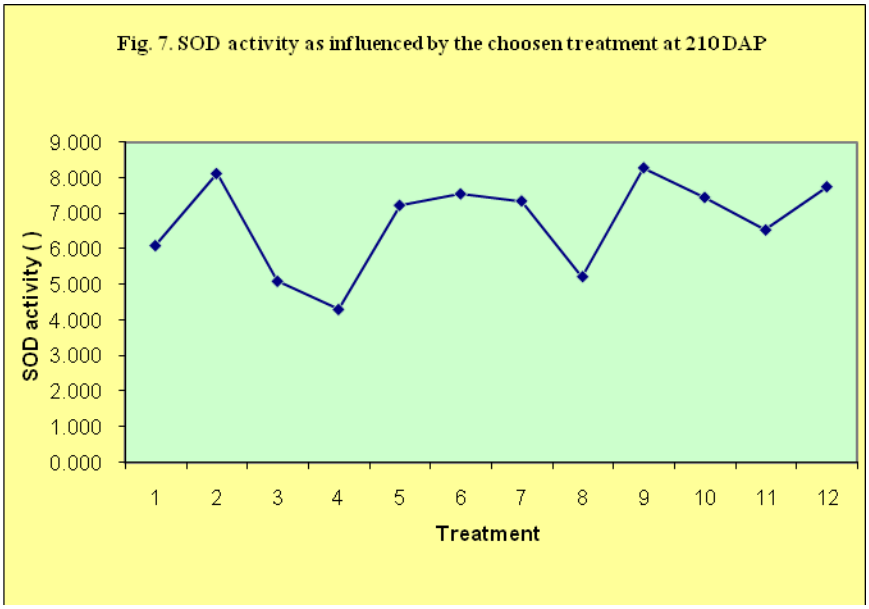


Fig. 8. Tillering capacity as influenced by the treatments 100 DAP

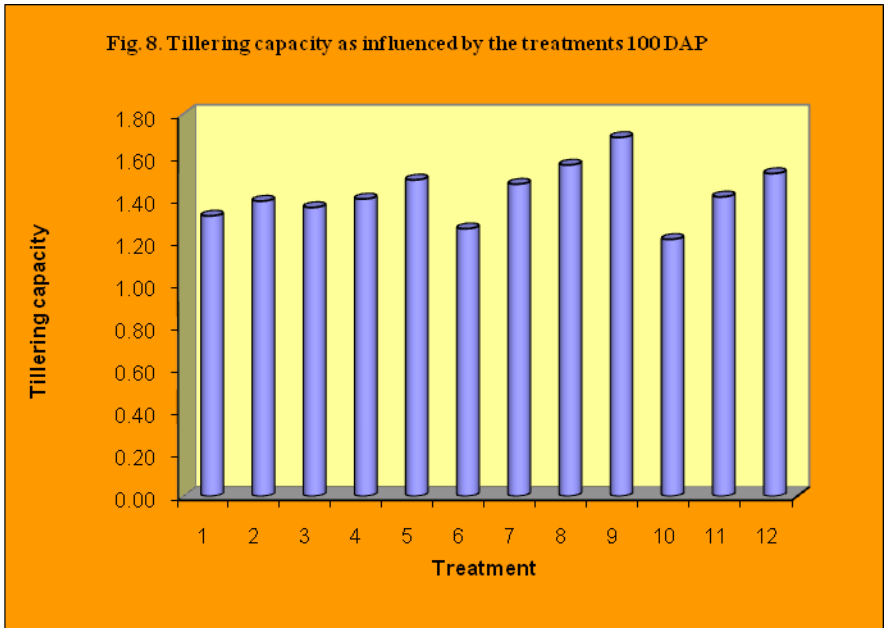


Fig. 9. Number of millable cane as influenced by treatments at harvest

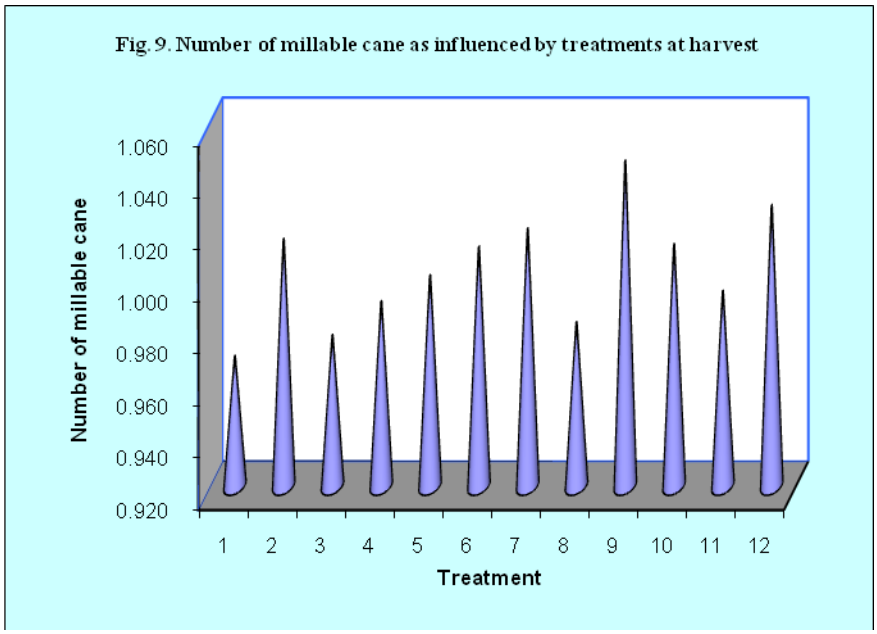


Fig. 10. Millable cane weight as influenced by the treatments at harvest

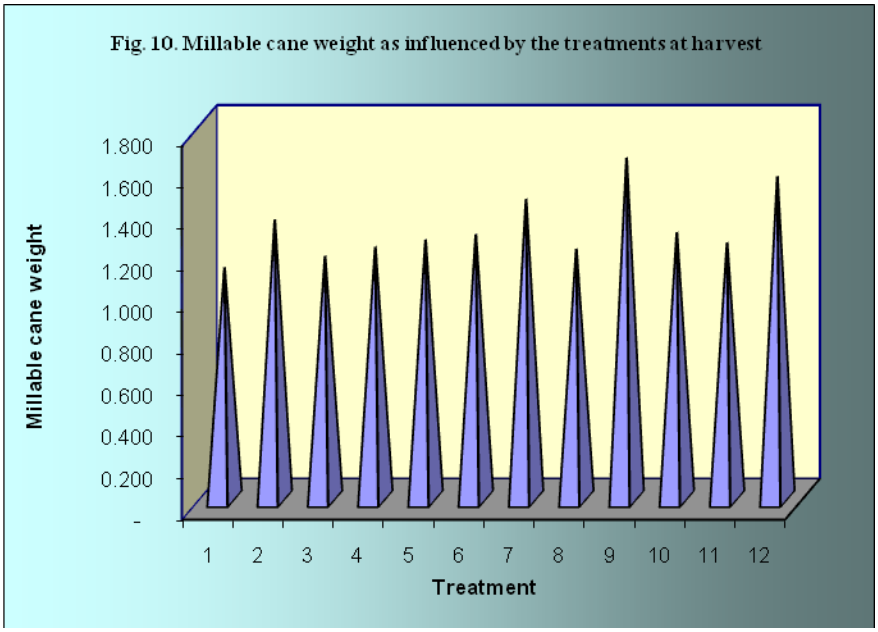


Fig. 11. Millable cane height as influenced by the treatments at harvest

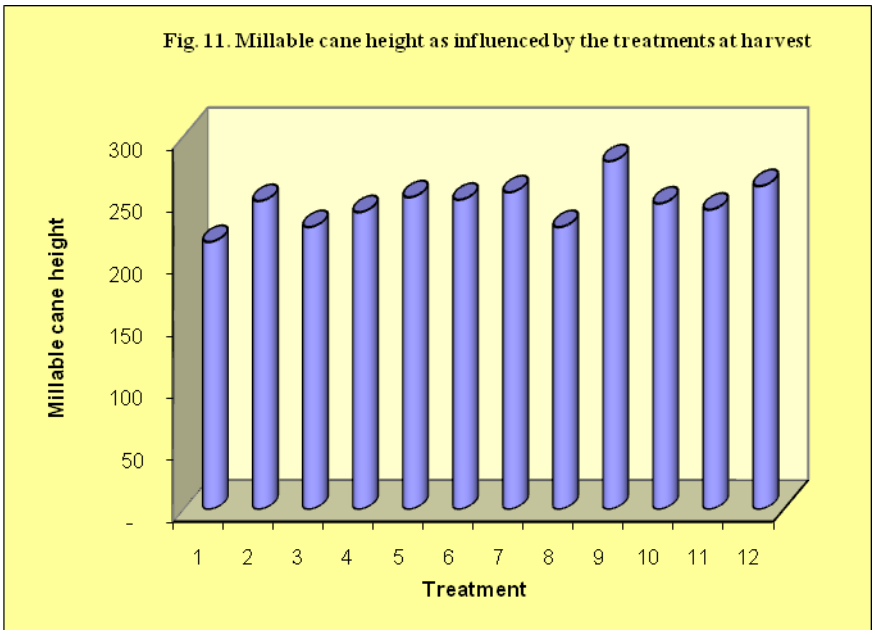


Fig. 12. Sucrose percentage in cane juice as influenced by the treatments

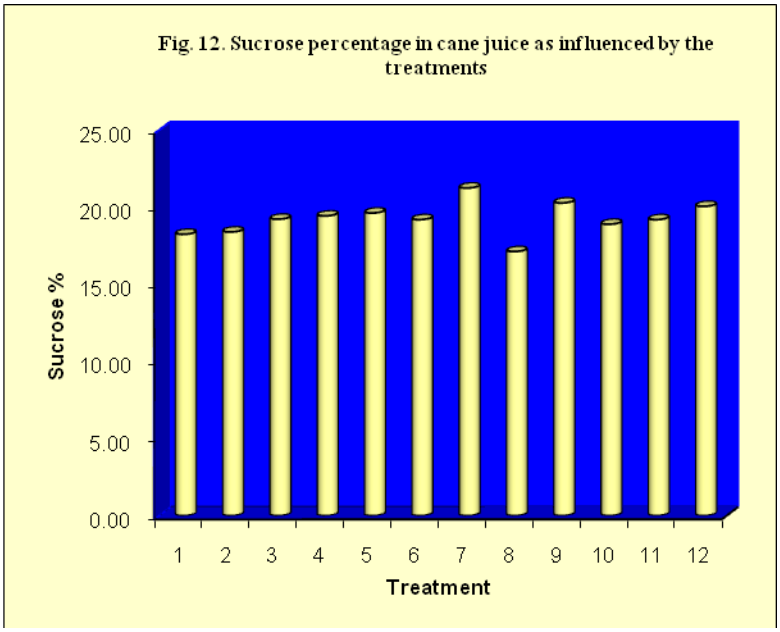


Fig. 13. Brix rate of the cane juice as influenced by the treatments at harvest

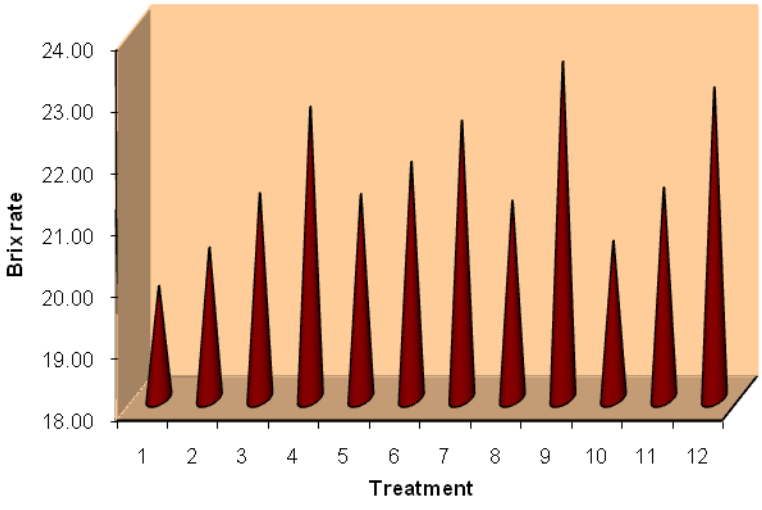


Fig. 14. Photosystem II efficiency (Fv/Fm) ratio as influenced by the treatments at 210 DAP

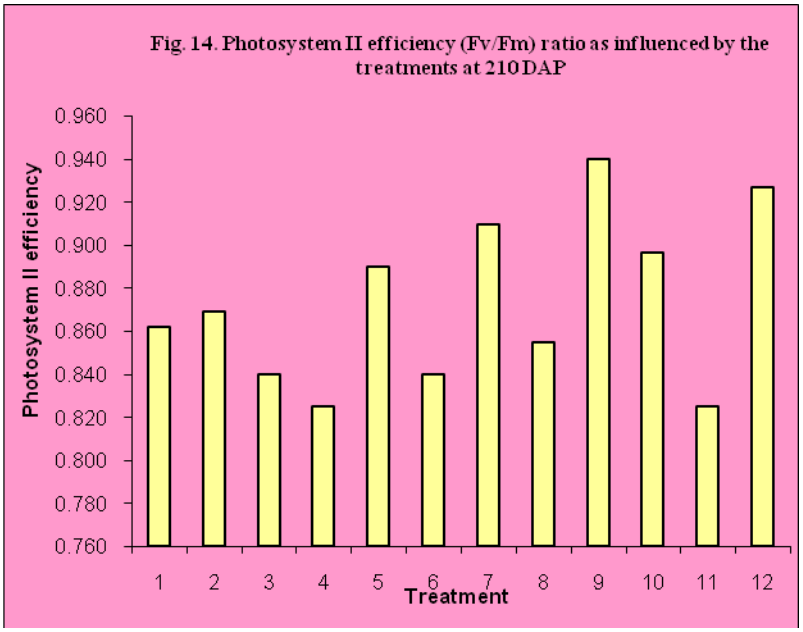


Fig. 15. SPAD chlorophyll meter readings as influenced by the treatments at 210 DAP

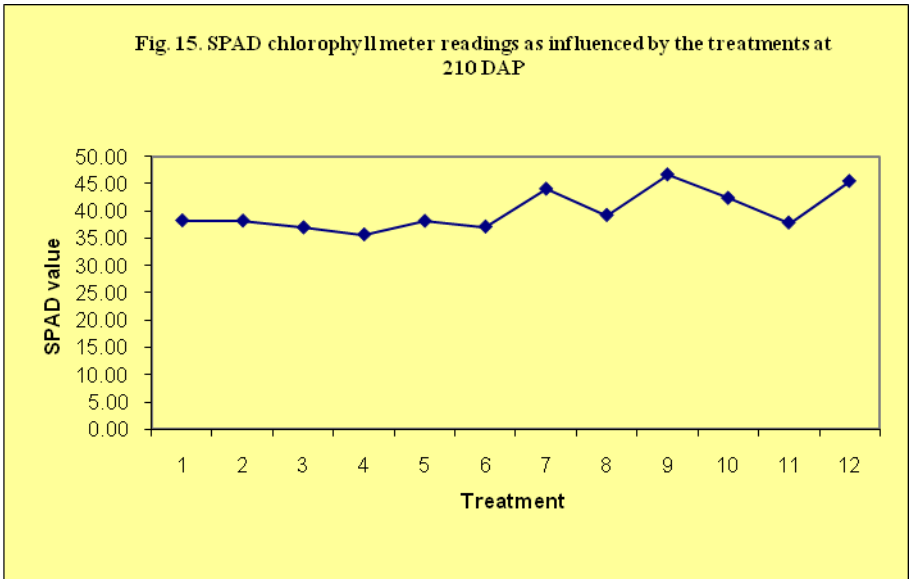


Fig. 16. Cane girth as influenced by the treatments at harvest

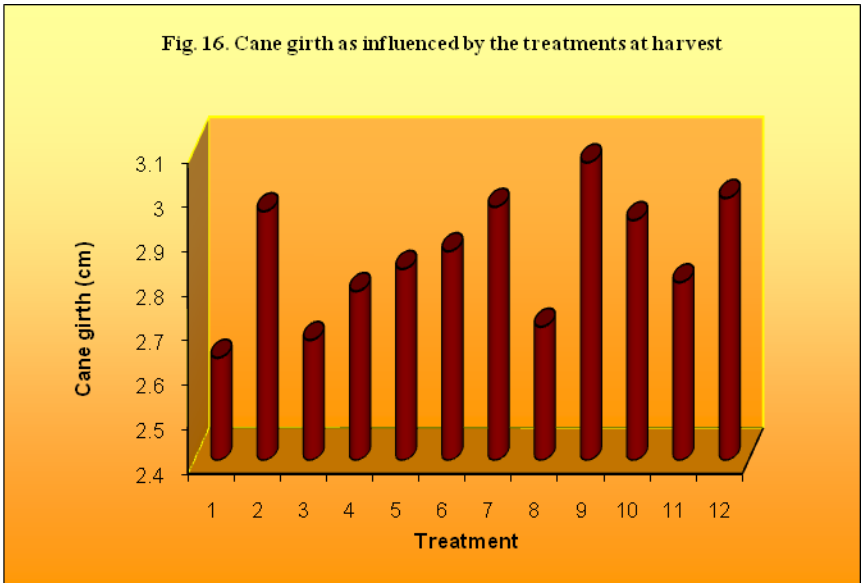


Fig. 17. Number of internodes as influenced by the treatments at harvest

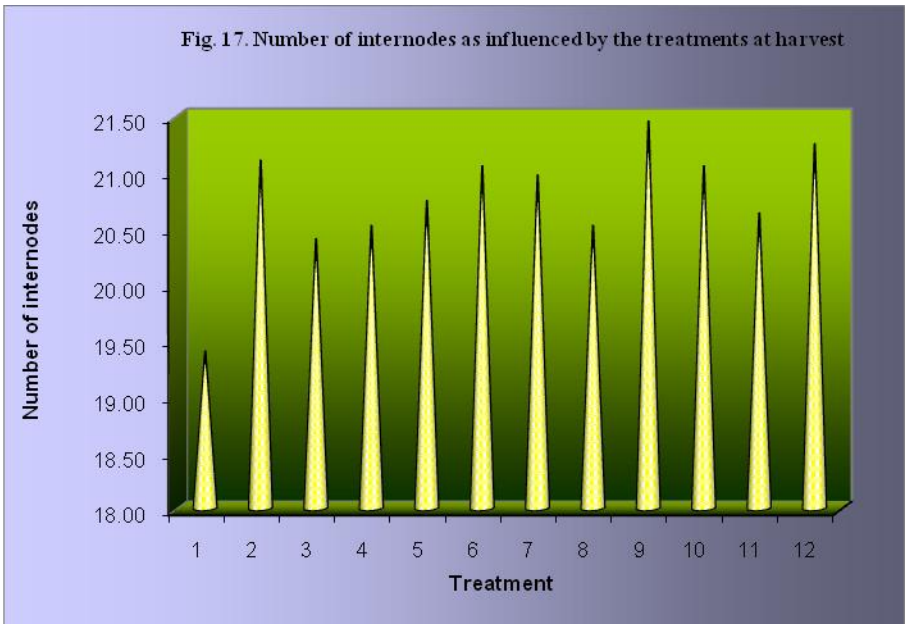


Fig. 18. Commercial cane sugar (CCS) as influenced by the treatments at harvest

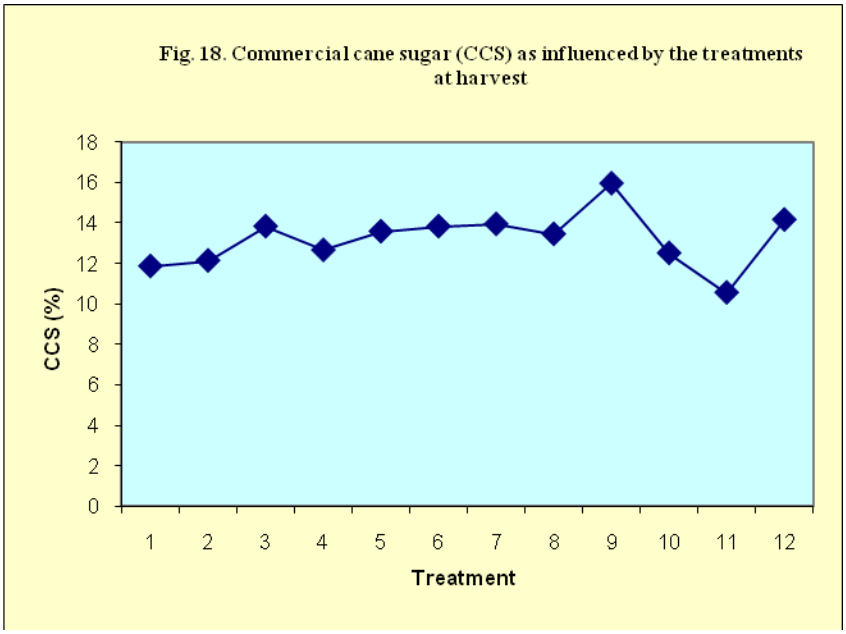


Fig. 19. Cane yield as influenced by the treatments

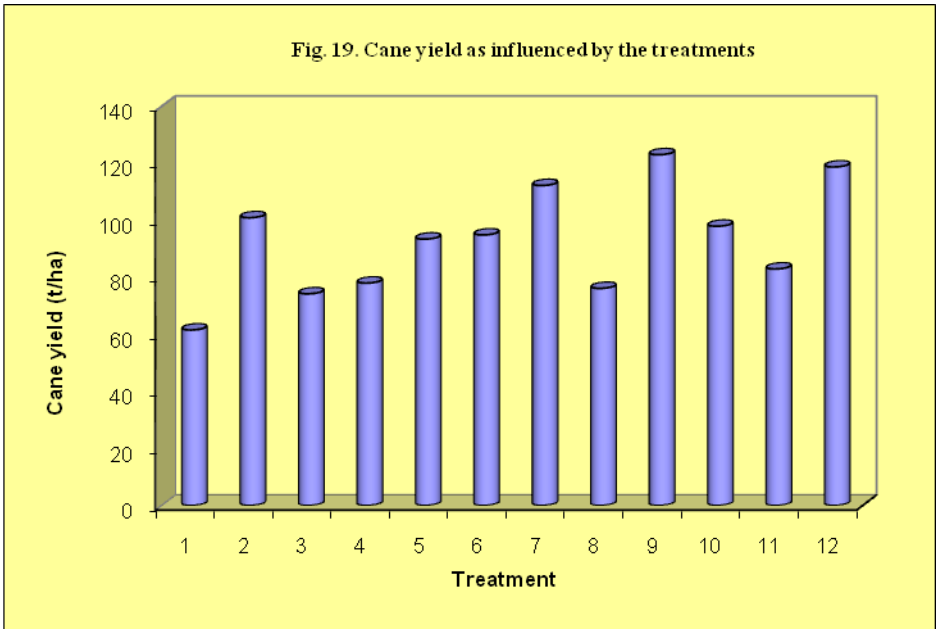


Fig. 20. Sugar yield as influenced by the treatments

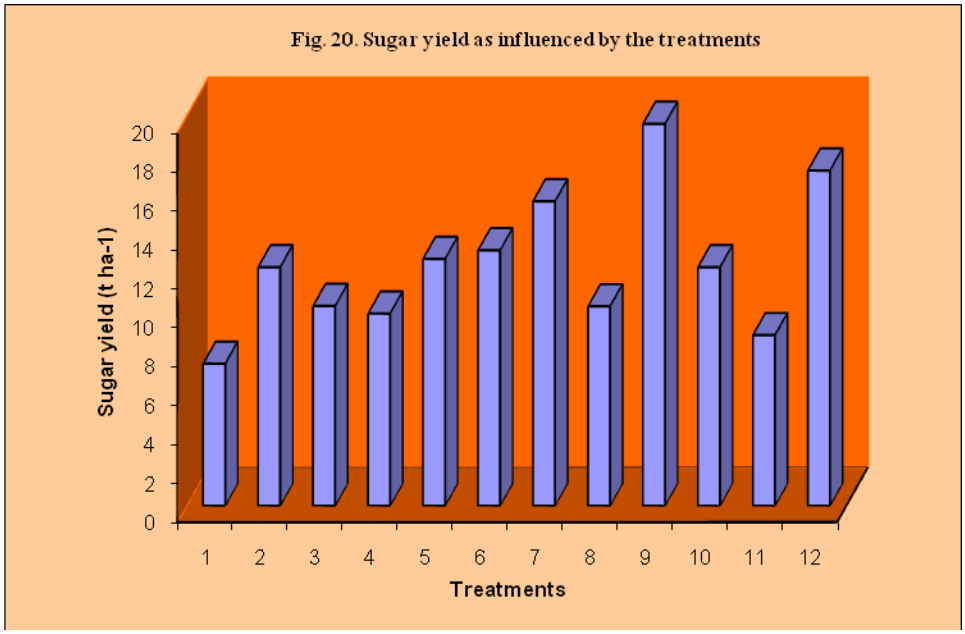
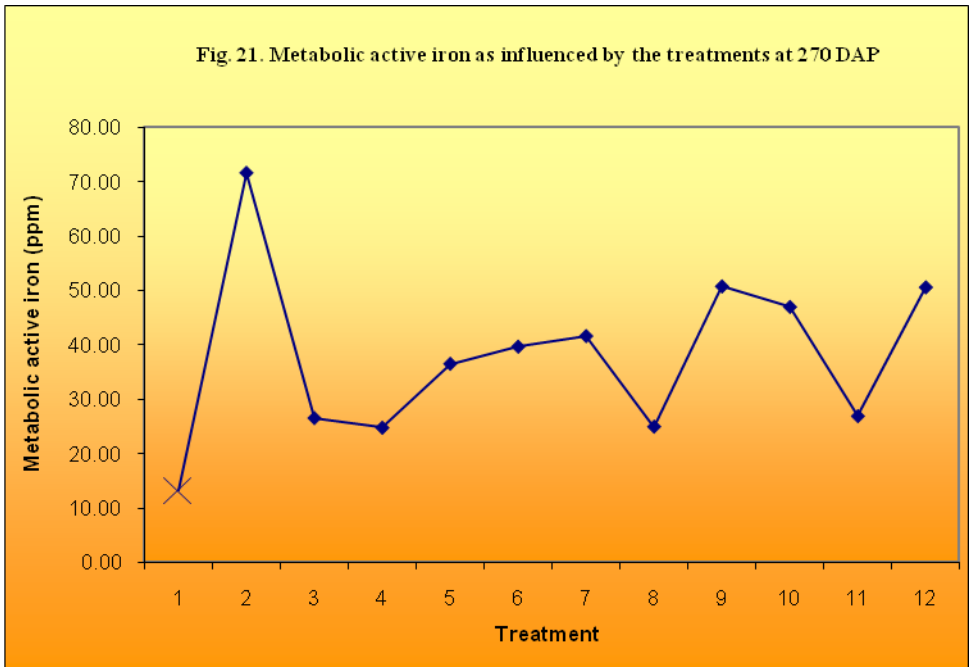


Fig. 21. Metabolic active iron as influenced by the treatments at 270 DAP



Physiological aspects of Iron nutrition in Sugarcane

Student : M.Antony Joseph Ravi Savery

Chairman : Dr. G.Dharmaraj

Members : Dr.S.Mohandass
: Dr. R.Jayakumar
: Dr. S.Manoharan

SUGARCANE *(Saccharum officinarum)*

- world's most important cash crop.
- major source of sugar and sweeteners cultivated in more than 120 countries in the world.
- cultivated commercially in 12 m ha in tropical and subtropical regions.
- Brazil, India, & Cuba account for 2/3 rd of the world cane production.

	Acreage	Production	Average yld / ha	Recovery %
All India	5.51 m ha	34 m mt	69.0 t / ha	10.17
Tamil Nadu	3.91 lakh ha	411 lakh mt	105.1 t / ha	9.25
Pondicherry	2000 ha	1lakh 60 thousand tonnes		8.31

Nutrient requirements for Sugarcane

- Three major nutrients (N, P & K)
- Three sec. nutrients (Ca, Mg & S)
- Six micronutrients (Fe, Mn, Zn, B, Cu & Mo) are indispensable for Sugarcane (Singh, 1978).

Role of Iron

- Iron though not a constituent of chlorophyll is essential for chlorophyll formation.
- Acts as catalyst in respiration and photosynthesis.
- Present in enzymes in small quantities and essential for enzyme activities.

Role of Iron in Sugarcane

- Most common micronutrient that limits cane productivity.
- Required for high yield, sugar recovery and juice quality.
- Deficiency causes reduction in cane yield up to 74 % and juice quality up to 42 %.

Causative factors of Iron chlorosis

- Fe/ Mn ratio less than 15:1 highly conducive for iron chlorosis (Humbert and Martin, 1955)
- High Ca Co_3 in the soil 1.5 – 2.0 per cent (Fogliata and Bustos, 1980)
- High HCO_3 renders iron unavailable for chlorophyll synthesis at active sites (Evans, 1959)
- High P renders iron unavailable to plants (Naidu *et al*., 1980)
- Chlorotic plants grown in black soil had high Fe and low Mn – Imbalances like high P/Fe ratio (Srivatsava, 1980)

Objectives

- To alleviate iron chlorosis through foliar application of micronutrients.
- To study the combined effect of micronutrients / PGR s on growth, yield and juice quality in sugarcane.
- To elucidate the physiological/ biochemical mechanism for treatment variation and to study the utilization efficiency of iron with respect to yield and juice quality in sugarcane.

Treatments

T_1	:	Control
T_2	:	1 % $FeSO_4$ spray @ 45,60 and 75DAP
T_3	:	1 ppm Brassinolide spray @ 45,60 and 75DAP
T_4	:	150 ppm Salicylic Acid spray @ 45,60 and 75DAP
T_5	:	1 %$FeSO_4$ +0.5 % $ZnSO_4$ spray @ 45,60 and 75DAP
T_6	:	1 %$FeSO_4$ + 0.5 % $MnSO_4$ spray- @ 45,60 and 75DAP
T_7	:	1 %$FeSO_4$ + 0.5 % $ZnSO_4$+ 0.5 % $MnSO_4$ spray @ 45,60 and 75DAP
T_8	:	1 ppm Brassinolide + 150 ppm Salicylic Acid spray @ 45,60 and 75DAP
T_9	:	$T_7 + T_3$
T_{10}	:	$T_9 + T_4$
T_{11}	:	Soil application of Micronutrient mixture @ 5 Kg@ 45,60 and 75DAP
T_{12}	:	Soil application of Micronutrient mixture @ 5 Kg + 1 ppm Brassinolide + 150 ppm Salicylic Acid spray@ 45,60 and 75DAP

Replication : Three Design : RBD

Observations recorded

Biometric observations

I. Tiller number (100 DAP)
II. Economic shoot population (120 DAP)

Growth analysis

i. Leaf area
ii. Leaf area Index
iii. Net assimilation rate (mg cm-2 day-1)
iv. Relative Growth rate
v. Crop Growth rate
vi. Leaf area duration
vii. Specific Leaf area
viii. Specific Leaf weight

Physiological / Biochemical parameters

i. Net photosynthetic rate
ii. Transpiration rate
iii. Stomatal conductance
iv. Chlorophyll meter readings (SPAD Values)
v. PS II Efficiency (Fv/Fm)
vi. Chlorophyll content
vii. Soluble protein
viii. CEC of roots
ix. Catalase activity
x. Peroxidase activity
xi. Superoxide dismutase activity

Nutritional status

i. Iron (Root / Soil)
ii. Manganese (Root / Soil)
iii. Phosphorus (Root / Soil)
iv. Metabolically active iron

Yield parameters

i. Number of millable canes
ii. Cane height, girth & No. of internodes
iii. Internodal length
iv. Single cane weight
v. Cane yield

Cane juice quality parameters

i. Brix %
ii. Pol % (Sucrose %)
iii. Purity coefficient
iv. Reducing sugars
v. CCS %
VI. Sugar yield

Effect of chosen treatments on Tillering capacity (lakh ha^{-1}) and Shoot population (lakh ha^{-1})

Treatments	Tillering capacity (lakh ha^{-1}) (100 DAP)	Economic shoot population (lakh ha^{-1}) (120 DAP)
T_1. Control	1.30	1.61
T_2. 1 % FeSO4	1.45	1.82
T_3. 1 ppm BR	1.34	1.62
T_4. 150 ppm SA	1.38	1.67
T_5. 1 %FeSO4 +0.5 %ZnSO4	1.47	1.75
T_6. 1 %FeSO4 + 0.5 % MnSO4	1.24	1.77
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	1.37	1.84
T_8. 1 ppm BR+150 ppm SA	1.50	1.65
T_9. T_7 + T_3	1.67 (2.84%)	1.88 (1.67%)
T_{10}. T_9 + T_4	1.19	1.79
T_{11}. Soil appl. micronutrients@ 5 Kg	1.39	1.70
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	1.54 (1.85%)	1.86 (1.55%)
Mean	1.40	1.75

Effect of chosen treatments on leaf area index

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	1.65	1.98	2.25	3.12	3.87	4.71	2.93
T_2. 1 % FeSO4	1.81	2.10	2.35	3.33	4.31	5.3	3.20
T_3. 1 ppm BR	1.75	2.06	2.32	3.17	3.93	4.84	3.01
T_4. 150 ppm SA	1.68	1.94	2.29	3.12	3.91	4.87	2.97
T_5. 1 %FeSO4 +0.5 %ZnSO4	1.69	1.95	2.27	3.09	3.97	4.95	2.99
T_6. 1 %FeSO4 + 0.5 % MnSO4	1.82	2.14	2.45	3.25	4.15	5.02	3.14
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	1.84	2.17	2.5	3.47	4.36	5.26	3.27
T_8. 1 ppm BR+150 ppm SA	1.71	2.02	2.32	3.12	3.94	4.82	2.99
T_9. T_7 + T_3	1.90	2.35	2.81	3.96	5.02	5.97	3.67 (25.2 %)
T_{10}. T_5 + T_4	1.85	2.26	2.6	3.35	4.19	5.11	3.23
T_{11}. Soil appl. micronutrients@ 5 Kg	1.78	2.08	2.4	3.15	3.96	4.91	3.05
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	1.87	2.30	2.65	3.70	4.64	5.62	3.46 (18.2 %)
Mean	1.78	2.11	2.43	3.32	4.19	5.12	3.71

Effect of chosen treatments on Net assimilation rate (mg cm^{-2} day^{-1})

Treatment	55- 70 DAP	70- 90 DAP	90- 150 DAP	150-210 DAP	210-270 DAP	Mean
T_1. Control	21.54	25.50	28.50	29.25	22.65	25.49
T_2. 1 % FeSO4	32.50	36.25	38.25	37.65	31.65	35.26
T_3. 1 ppm BR	27.75	30.45	31.25	30.18	24.35	28.80
T_4. 150 ppm SA	28.65	31.57	32.75	33.25	28.52	30.95
T_5 . 1 %FeSO4 +0.5 %ZnSO4	30.87	33.25	35.85	36.15	30.57	33.34
T_6 . 1 %FeSO4 + 0.5 % MnSO4	31.47	32.15	34.57	35.75	30.15	32.82
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	30.65	36.45	38.70	39.25	34.47	35.90
T_8. 1 ppm BR+150 ppm SA	30.15	32.57	35.65	34.15	29.25	32.35
T_9. T_7 + T_3	32.50	39.25	41.54	42.15	36.54	38.40 (50.65 %)
T_{10}. T_9 + T_4	31.45	33.75	36.21	36.37	30.75	33.71
T_{11}. Soil appl. micronutrients@ 5 Kg	29.77	31.65	34.75	34.25	29.54	31.99
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	31.75	35.75	39.78	40.78	35.45	36.70 (43.97 %)
Mean	29.92	33.22	35.65	35.77	30.32	32.98

Effect of chosen treatments on Crop growth rate (g m^{-2} day^{-1})

Treatment	55-70 DAP	70-90DAP	90-150 DAP	150-210 DAP	210-270 DAP	Mean
T_1. Control	4.92	5.41	7.67	10.90	9.70	7.72
T_2. 1 % FeSO4	6.37	8.08	8.57	14.40	15.20	10.52
T_3. 1 ppm BR	5.30	6.69	8.59	10.71	10.60	8.38
T_4. 150 ppm SA	5.19	6.69	8.88	11.70	12.50	8.99
T_5. 1 %FeSO4 +0.5 %ZnSO4	5.62	7.02	9.61	12.80	13.60	9.73
T_6. 1 %FeSO4 + 0.5 % MnSO4	6.23	7.39	9.85	13.20	13.80	10.09
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	6.64	8.87	12.70	7.00	18.20	10.68
T_8. 1 ppm BR+150 ppm SA	5.64	7.07	9.70	12.10	12.80	9.46
T_9. T_7 + T_3	6.92	10.10	14.10	18.90	20.40	14.08 (82 %)
T_{10}. T_9 + T_4	6.48	8.20	10.80	13.70	14.30	10.70
T_{11}. Soil appl. micronutrients@ 5 Kg	5.75	7.90	9.66	12.20	13.10	9.72
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	6.16	8.53	11.60	15.40	16.60	11.66 (51 %)
Mean	5.94	7.66	10.14	12.75	14.23	10.15

Effect of chosen treatments on Relative growth rate (mg g^{-1} day^{-1})

Treatment	55- 70 DAP	70-90 DAP	90- 150 DAP	150- 210 DAP	210-270 DAP	Mean
T_1. Control	34.66	15.71	18.42	7.54	2.93	15.85
T_2. 1 % FeSO4	35.57	15.99	18.55	8.31	3.67	16.42
T_3. 1 ppm BR	36.01	15.91	18.53	7.58	2.93	16.19
T_4. 150 ppm SA	35.84	16.81	18.7	7.55	3.47	16.47
T_5. 1 %FeSO4 +0.5 %ZnSO4	37.33	16.28	18.76	7.70	3.14	16.64
T_6. 1 %FeSO4 + 0.5 % MnSO4	35.53	15.94	18.52	8.46	2.99	16.29
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	35.26	15.4	18.99	8.38	3.82	16.37
T_8. 1 ppm BR+150 ppm SA	34.70	15.36	19.03	7.21	3.09	15.88
T_9. T_7 + T_3	39.64	15.95	18.9	8.63	3.69	17.36 (15 %)
T_{10}. T_9 + T_4	35.80	15.01	18.61	7.79	3.60	16.16
T_{11}. Soil appl. micronutrients@ 5 Kg	36.02	15.82	17.98	7.80	2.95	16.11
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	39.19	15.50	18.83	8.96	3.91	17.28 (14 %)
Mean	36.30	15.81	18.65	7.99	3.35	16.42

Effect of chosen treatments on Leaf area duration (Days)

Treatment	55-70 DAP	70-90 DAP	90-150 DAP	150-210 DAP	210-270 DAP	Mean
T_1. Control	27.20	42.30	161.10	209.70	257.40	139.54
T_2. 1 % FeSO4	29.30	44.50	170.40	229.20	288.30	152.34
T_3. 1 ppm BR	28.60	43.80	164.70	213.00	263.10	142.64
T_4. 150 ppm SA	27.20	42.30	162.30	210.90	263.40	141.22
T_5. 1 %FeSO4 +0.5 %ZnSO4	27.30	42.20	160.80	211.80	267.60	141.94
T_6. 1 %FeSO4 + 0.5 % MnSO4	29.70	45.90	171.00	222.00	275.10	148.74
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	30.10	46.70	179.10	234.90	288.60	155.88
T_8. 1 ppm BR+150 ppm SA	27.90	43.40	163.20	250.20	262.80	149.50
T_9. T_7 + T_3	**31.90**	**51.60**	**203.10**	**269.40**	**363.20**	**183.84 (31 %)**
T_{10}. T_9 + T_4	30.80	48.60	178.50	226.20	2790	152.62
T_{11}. Soil appl. micronutrients@ 5 Kg	28.90	44.80	166.50	213.30	266.10	143.92
T_{12}. T_{11} + 1 ppm BR + 150 ppm SA	**31.30**	**49.50**	**190.50**	**226.20**	**307.80**	**161.06 (15 %)**
Mean	29.20	45.47	172.60	226.40	281.87	154.44

Effect of chosen treatments on specific leaf area (cm^{-2} g^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	125.00	131.50	136.25	140.75	142.50	146.10	137.02
T_2. 1 % FeSO4	135.50	140.250	146.50	150.25	153.50	156.70	147.12
T_3. 1 ppm BR	133.10	136.50	140.70	144.60	148.250	150.90	142.34
T_4. 150 ppm SA	126.30	130.25	133.80	136.70	140.50	144.80	135.39
T_5. 1 %FeSO4 +0.5 %ZnSO4	128.50	135.65	148.20	150.25	155.25	158.50	146.06
T_6. 1 %FeSO4 + 0.5 % MnSO4	136.80	140.75	144.60	148.25	152.30	158.00	146.78
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	139.90	141.25	143.65	145.65	148.80	150.70	144.99
T_8. 1 ppm BR+150 ppm SA	128.10	133.25	137.50	140.60	143.25	150.20	138.82
T_9. T_7 + T_3	**143.40**	**150.50**	**156.80**	**162.50**	**168.25**	**172.80**	**159.04 (16 %)**
T_{10}. T_9 + T_4	140.20	145.35	151.35	155.10	161.75	166.20	153.33
T_{11}. Soil appl. micronutrients@ 5 Kg	133.30	139.75	141.10	143.25	150.15	154.70	143.71
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	**142.20**	**146.25**	**150.25**	**157.25**	**162.70**	**169.70**	**154.73 (12.9 %)**
Mean	134.36	139.27	144.23	147.93	152.27	156.61	145.78

Effect of chosen treatments on specific leaf weight (mg cm^{-2})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	8.68	8.50	8.25	7.77	7.61	7.42	8.04
T_2. 1 % FeSO4	8.50	8.04	7.67	7.22	7.06	7.05	7.59
T_3. 1 ppm BR	8.35	8.23	7.98	7.50	7.31	7.18	7.76
T_4. 150 ppm SA	8.90	7.58	7.19	6.68	6.44	6.27	7.18
T_5. 1 %FeSO4 +0.5 %ZnSO4	8.44	8.28	7.58	7.22	6.98	6.84	7.56
T_6. 1 %FeSO4 + 0.5 % MnSO4	8.58	8.02	7.77	7.32	7.13	6.86	7.61
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	8.72	7.77	7.48	6.90	6.66	6.39	7.32
T_8. 1 ppm BR+150 ppm SA	8.77	8.00	7.83	7.45	7.29	7.19	7.76
T_9. T_7 + T_3	**8.60**	**8.57**	**8.40**	**7.93**	**7.72**	**7.49**	**8.12**
T_{10}. T_9 + T_4	8.70	7.81	7.43	6.99	6.72	6.52	7.36
T_{11}. Soil appl. micronutrients@ 5 Kg	8.36	8.07	7.97	7.57	7.22	7.01	7.70
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	8.46	8.40	8.18	7.71	7.57	7.22	7.92
Mean	8.60	8.08	7.78	7.32	7.10	6.93	7.64

Effect of chosen treatments on Net photosynthetic rate (μ mol m^{-2} s^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	12.07	12.77	13.45	14.4	14.97	14.32	13.66
T_2. 1 % FeSO4	12.24	13.28	13.71	14.66	15.15	14.4	13.91
T_3. 1 ppm BR	12.07	12.20	13.11	14.04	14.57	14.25	13.37
T_4. 150 ppm SA	11.91	12.41	12.85	13.9	14.4	13.91	13.23
T_5. 1 %FeSO4 +0.5 %ZnSO4	12.17	13.54	14.31	15.16	15.55	14.66	14.23
T_6. 1 %FeSO4 + 0.5 % MnSO4	12.27	12.67	13.11	14.11	14.65	14.31	13.52
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	12.41	12.69	14.57	15.77	16	15.28	14.45
T_8. 1 ppm BR+150 ppm SA	12.00	13.11	13.54	14.63	14.93	13.6	13.64
T_9. T_7 + T_3	12.80	13.80	15.25	16.19	16.48	16.08	15.10 (10.5 %)
T_{10}. T_9 + T_4	12.65	13.11	13.62	14.84	15.73	14.75	14.12
T_{11}. Soil appl. micronutrients@ 5 Kg	11.91	12.51	12.89	13.86	14.22	13.24	13.11
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	12.46	13.02	14.91	16.35	15.25	15.57	14.59 (6.8 %)
Mean	12.25	12.93	13.78	14.83	15.16	14.53	13.91

Effect of chosen treatments on Transpiration rate (m mol m^{-2} s^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	0.402	0.431	0.451	0.485	0.510	0.491	0.462
T_2. 1 % FeSO4	0.410	0.462	0.467	0.495	0.512	0.485	0.472
T_3. 1 ppm BR	0.419	0.415	0.445	0.475	0.495	0.482	0.455
T_4. 150 ppm SA	0.399	0.423	0.439	0.478	0.497	0.485	0.454
T_5. 1 %FeSO4 +0.5 %ZnSO4	0.417	0.465	0.482	0.520	0.530	0.492	0.484
T_6. 1 %FeSO4 + 0.5 % MnSO4	0.412	0.435	0.445	0.481	0.497	0.485	0.459
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	0.421	0.429	0.495	0.535	0.548	0.525	0.492
T_8. 1 ppm BR+150 ppm SA	0.399	0.436	0.451	0.497	0.510	0.465	0.460
T_9. T_7 + T_3	0.425	0.439	0.510	0.545	0.515	0.525	0.493 (6.7 %)
T_{10}. T_9 + T_4	0.427	0.440	0.459	0.510	0.547	0.510	0.482
T_{11}. Soil appl. micronutrients@ 5 Kg	0.399	0.427	0.453	0.499	0.540	0.495	0.469
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	0.437	0.471	0.512	0.545	0.565	0.545	0.513 (14.7%)
Mean	0.414	0.439	0.467	0.505	0.522	0.499	0.475

Effect of chosen treatments on stomatal conductance (m mol m^{-2} s^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	187.60	198.40	209.00	223.80	232.70	222.50	212.33
T_2. 1 % FeSO4	190.20	206.30	213.00	227.80	235.40	223.80	216.08
T_3. 1 ppm BR	187.50	189.50	203.70	218.20	226.40	221.50	207.80
T_4. 150 ppm SA	185.10	192.80	194.30	216.00	223.80	216.20	204.70
T_5. 1 %FeSO4 +0.5 %ZnSO4	189.70	210.41	222.37	235.60	241.70	227.80	221.26
T_6. 1 %FeSO4 + 0.5 % MnSO4	190.67	196.89	203.72	219.30	227.80	222.40	210.13
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	192.85	197.20	226.40	245.10	248.60	237.50	224.61
T_8. 1 ppm BR+150 ppm SA	186.50	203.70	210.40	229.40	232.00	211.30	212.22
T_9. T_7 + T_3	198.90	214.50	236.90	251.60	256.10	249.90	234.65 (10 %)
T_{10}. T_9 + T_4	196.60	203.70	211.70	230.60	244.40	229.20	219.37
T_{11}. Soil appl. micronutrients@ 5 Kg	185.10	194.40	200.30	215.40	220.90	205.80	203.65
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	193.60	202.30	231.70	254.10	236.90	241.90	226.75 (5 %)
Mean	190.36	200.84	213.62	230.58	235.56	225.82	216.13

Effect of chosen treatments on SPAD values

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	32.02	32.84	34.26	36.04	37.67	33.81	34.44
T_2. 1 % FeSO4	32.40	32.67	34.08	35.57	37.43	34.79	34.49
T_3. 1 ppm BR	32.93	34.38	34.65	35.55	36.79	35.18	34.91
T_4. 150 ppm SA	31.35	32.16	32.99	34.12	35.01	31.91	32.92
T_5. 1 %FeSO4 +0.5 %ZnSO4	31.71	33.07	34.78	36.90	37.87	34.53	34.81
T_6. 1 %FeSO4 + 0.5 % MnSO4	32.77	33.90	35.07	35.68	36.62	35.01	34.84
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	34.82	38.43	40.12	42.97	43.74	37.86	39.66
T_8. 1 ppm BR+150 ppm SA	34.35	35.04	37.09	37.74	38.97	33.62	36.14
T_9. T_7 + T_3	37.44	41.71	43.27	43.97	45.04	44.40	42.64 (24 %)
T_{10}. T_9 + T_4	33.26	34.69	36.51	38.75	41.42	35.94	36.76
T_{11}. Soil appl. micronutrients@ 5 Kg	31.70	33.06	34.77	36.31	36.93	32.06	34.14
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	36.74	39.54	41.78	42.51	44.45	41.28	41.05 (19 %)
Mean	33.46	35.12	36.61	38.01	39.33	35.87	36.40

Effect of chosen treatments on Chlorophyll fluorescence - (Fv/Fm)

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	0.710	0.750	0.795	0.817	0.862	0.812	0.791
T_2. 1 % FeSO4	0.720	0.795	0.820	0.835	0.869	0.825	0.811
T_3. 1 ppm BR	0.715	0.725	0.780	0.810	0.840	0.827	0.783
T_4. 150 ppm SA	0.720	0.742	0.765	0.798	0.825	0.752	0.767
T_5. 1 %FeSO4 +0.5 %ZnSO4	0.727	0.810	0.847	0.868	0.890	0.840	0.830
T_6. 1 %FeSO4 + 0.5 % MnSO4	0.730	0.750	0.780	0.810	0.840	0.827	0.790
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	0.741	0.755	0.865	0.899	0.910	0.881	0.842
T_8. 1 ppm BR+150 ppm SA	0.725	0.782	0.810	0.840	0.855	0.780	0.799
T_9. T_7 + T_3	0.760	0.820	0.910	0.925	0.940	0.920	0.879 (11 %)
T_{10}. T_9 + T_4	0.750	0.780	0.815	0.850	0.897	0.850	0.824
T_{11}. Soil appl. micronutrients@ 5 Kg	0.710	0.745	0.767	0.795	0.825	0.760	0.767
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	0.740	0.775	0.885	0.920	0.927	0.825	0.845 (6.8%)
Mean	0.729	0.769	0.820	0.847	0.873	0.825	0.811

Effect of chosen treatments on chlorophyll 'a 'content (mg g^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1- Control	0.653	0.941	1.200	1.361	1.622	1.372	1.192
T_2- 1 % $FeSO_4$	0.700	0.997	1.254	1.437	1.762	1.497	1.275
T_3. 1 ppm BR	0.737	1.029	1.029	1.430	1.715	1.452	1.232
T_4. 150 ppm SA T_4. 150 ppm SA	0.705	1.002	1.002	1.443	1.775	1.419	1.224
T_5- 1 %$FeSO_4$ +0.5 %$ZnSO_4$	0.728	0.103	1.031	1.465	1.698	1.552	1.096
T_6- 1 %$FeSO_4$ + 0.5 % MnSO4	0.725	1.045	1.045	1.477	1.764	1.625	1.280 (7%)
T_7- 1 %$FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$	0.715	1.033	1.033	1.430	1.659	1.536	1.234
T_8- 1 ppm BR+150 ppm SA	0.667	0.997	0.997	1.356	1.688	1.623	1.221
T_9 – T_7 + T_3	0.742	1.039	1.039	1.497	1.826	1.602	1.291 (8.3%)
T_{10} – T_9 + T_4	0.715	1.032	1.032	1.419	1.623	1.501	1.220
T_{11} – Soil appl. micronutrients@ 5 Kg	0.687	0.949	0.949	1.337	1.552	1.384	1.143
T_{12} – T_{11}+ 1ppm BR + 150 ppm SA	0.740	1.036	1.036	1.151	1.845	1.646	1.076
Mean	0.710	0.934	1.054	1.400	1.711	1.517	1.207

Effect of chosen treatments on chlorophyll 'b'content (mg g^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1- Control	0.264	0.373	0.463	0.513	0.608	0.505	0.454
T_2- 1 % $FeSO_4$	0.278	0.387	0.471	0.523	0.648	0.534	0.474
T_3- 1 ppm BR	0.266	0.391	0.467	0.513	0.617	0.510	0.461
T_3- 1 ppm BR	0.290	0.402	0.473	0.551	0.680	0.535	0.489
T_5- 1 %$FeSO_4$ +0.5 %$ZnSO_4$	0.291	0.393	0.452	0.514	0.587	0.546	0.464
T_6- 1 %$FeSO_4$ + 0.5 % MnSO4	0.290	0.411	0.491	0.537	0.661	0.602	0.499 (9.9%)
T_7- 1 %$FeSO_4$ +0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$	0.278	0.391	0.443	0.520	0.582	0.558	0.462
T_8- 1 ppm BR+150 ppm SA	0.271	0.382	0.461	0.490	0.615	0.575	0.466
T_9- T_7 +T_3	0.283	0.401	0.493	0.541	0.648	0.579	0.491 (8.1%)
T_{10}- T_9 + T_4	0.278	0.394	0.454	0.503	0.570	0.539	0.456
T_{11} Soil application of Micronutrient mixture @ 5 Kg	0.288	0.386	0.462	0.505	0.575	0.529	0.458
T_{12}- T_{11}+ Ippm BR + 150 ppm SA	0.277	0.377	0.472	0.513	0.605	0.564	0.468
Mean	0.280	0.391	0.467	0.519	0.616	0.548	0.470

Effect of chosen treatments on Total chlorophyll content (mg g^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1- Control	0.917	1.314	1.663	1.874	2.230	1.877	1.646
T_2- 1 % FeSO4	1.017	1.413	1.508	0.664	2.450	2.210	1.544
T_3- 1 ppm BR	1.003	1.420	1.717	1.943	2.332	1.962	1.730
T_4- 150 ppm SA	0.995	1.404	1.690	1.994	2.455	1.954	1.749
T_5- 1 %FeSO4 +0.5 %ZnSO4	1.019	1.424	1.690	1.979	2.285	2.098	1.749
T_6- 1 %FeSO4 + 0.5 % MnSO4	1.025	1.440	1.532	2.038	2.474	2.181	1.782 (8.26%)
T_7- 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	0.993	1.424	1.476	1.950	2.241	2.094	1.696
T_8- 1 ppm BR+150 ppm SA	0.938	1.359	1.692	1.846	2.303	2.198	1.723
T_9- T_7 + T_3	1.015	1.456	1.779	2.014	2.425	2.227	1.819 (10.5%)
T_{10}- T_9 + T_4	0.993	1.426	1.702	1.922	2.193	2.040	1.713
T_{11}- Soil appl. micronutrients@ 5 Kg	0.975	1.335	1.658	1.842	2.127	1.913	1.642
T_{12}- T_{11}+ 1 ppm BR + 150 ppm SA	0.978	1.384	1.725	1.960	2.410	2.031	1.748
Mean	0.989	1.400	1.653	1.836	2.327	2.065	1.712

Effect of chosen treatments on chlorophyll a /b ratio

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	2.47	2.52	2.59	2.65	2.67	2.72	2.60
T_2. 1 % FeSO4	2.52	2.58	2.66	2.75	2.72	2.80	2.67
T_3. 1 ppm BR	2.77	2.63	2.68	2.79	2.78	2.85	2.75
T_4. 150 ppm SA	2.43	2.49	2.57	2.62	2.61	2.65	2.56
T_5. 1 %FeSO4 +0.5 %ZnSO4	2.50	2.62	2.74	2.85	2.89	2.84	2.74
T_6. 1 %FeSO4 + 0.5 % MnSO4	2.49	2.54	2.62	2.75	2.67	2.70	2.63
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	2.57	2.64	2.76	2.75	2.85	2.75	2.72
T_8. 1 ppm BR+150 ppm SA	2.46	2.56	2.67	2.77	2.79	2.82	2.68
T_9. T_7 + T_3	2.67	2.75	2.84	2.95	3.05	2.92	2.86 (10%)
T_{10}. T_9 + T_4	2.57	2.62	2.75	2.82	2.85	2.78	2.73
T_{11}. Soil appl. micronutrients@ 5 Kg	2.38	2.46	2.59	2.65	2.70	2.61	2.57
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	2.62	2.59	2.69	2.77	2.82	2.75	2.71
Mean	2.54	2.58	2.68	2.76	2.78	2.77	2.69

Effect of chosen treatments on Soluble protein content (mg g^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	8.06	9.29	9.69	11.01	12.78	13.55	10.73
T_2. 1 % FeSO4	11.18	13.43	14.79	17.20	18.75	19.20	15.76
T_3. 1 ppm BR	11.10	13.10	14.00	16.50	18.20	19.50	15.40
T_4. 150 ppm SA	11.64	12.87	13.55	17.20	18.95	19.95	15.69
T_5. 1 %FeSO4 +0.5 %ZnSO4	11.65	12.95	13.90	16.85	18.65	19.80	15.63
T_6. 1 %FeSO4 + 0.5 % MnSO4	11.38	13.00	14.40	17.00	18.90	20.00	15.78
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	11.24	13.50	15.00	16.20	19.00	20.35	15.88
T_8. 1 ppm BR+ 150 ppm SA	11.50	13.05	13.50	15.90	18.40	19.85	15.37
T_9. T_7 + T_3	11.75	13.95	15.15	17.50	19.20	22.50	16.68 (55%)
T_{10}. T_9 + T_4	11.62	12.95	13.40	16.00	18.00	20.52	15.41
T_{11}. Soil appl. micronutrients@ 5 Kg	11.67	13.22	12.95	15.00	17.70	20.00	15.09
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	11.75	13.40	15.65	17.80	19.93	21.10	16.61 (54%)
Mean	11.21	12.89	13.83	16.18	18.21	19.69	15.34

Effect of chosen treatments on Cation exchange capacity (meq 100 g^{-1})

Treatment	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	14.24	15.35	16.60	15.40
T_2. 1 % FeSO4	18.10	18.95	20.65	19.23
T_3. 1 ppm BR	16.52	17.45	17.60	17.19
T_4. 150 ppm SA	16.75	17.45	17.80	17.33
T_5. 1 %FeSO4 +0.5 %ZnSO4	17.98	18.78	19.25	18.67
T_6. 1 %FeSO4 + 0.5 % MnSO4	18.01	18.86	20.61	19.16
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	18.84	19.42	20.74	19.67
T_8. 1 ppm BR+150 ppm SA	17.01	17.70	18.25	17.65
T_9. T_7 + T_3	20.50	19.97	21.96	20.81
T_{10}. T_9 + T_4	14.50	16.78	18.45	16.58
T_{11}. Soil appl. micronutrients@ 5 Kg	14.46	15.78	16.43	15.56
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	19.07	19.76	21.63	20.15
Mean	16.99	17.86	18.94	17.93

Effect of chosen treatments on Catalase activity (µg H_2O_2 g^{-1} min^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	1.08	1.16	1.19	1.23	1.20	1.15	1.17
T_2. 1 % FeSO4	11.34	11.65	12.50	13.90	14.30	14.12	12.97
T_3. 1 ppm BR	2.06	2.20	2.32	2.45	2.10	2.04	2.20
T_4. 150 ppm SA	2.92	2.90	3.00	3.15	3.00	2.85	2.97
T_5. 1 %FeSO4 +0.5 %ZnSO4	7.30	7.45	7.75	7.95	7.10	6.98	7.42
T_6. 1 %FeSO4 + 0.5 % MnSO4	7.22	7.30	7.40	7.55	6.85	6.62	7.16
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	2.32	2.40	2.55	2.75	2.45	2.32	2.47
T_8. 1 ppm BR+ 150 ppm SA	2.15	2.25	2.45	2.60	2.35	2.20	2.33
T_9. T_7 + T_3	6.50	6.70	6.90	7.15	7.05	6.87	6.86
T_{10}. T_9 + T_4	6.10	6.20	6.42	6.65	6.40	6.29	6.34
T_{11}. Soil appl. micronutrients@ 5 Kg	2.95	3.00	3.15	3.35	3.11	3.01	3.10
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	6.35	6.54	6.75	6.90	6.72	6.56	6.64
Mean	4.86	4.98	5.20	5.47	5.22	5.08	5.13

Effect of chosen treatments on Peroxidase activity (Δ430 nm g^{-1} min^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	0.94	1.09	1.41	1.61	1.89	1.89	1.47
T_2. 1 % FeSO4	3.12	3.35	3.99	4.13	4.31	4.43	3.89
T_3. 1 ppm BR	0.32	0.51	0.61	0.66	0.77	0.79	0.61
T_4. 150 ppm SA	0.40	0.59	0.59	0.62	0.65	0.67	0.59
T_5. 1 %FeSO4 +0.5 %ZnSO4	2.05	2.23	2.43	2.59	2.63	2.70	2.44
T_6. 1 %FeSO4 + 0.5 % MnSO4	1.47	1.99	2.10	2.29	2.34	2.45	2.11
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	1.21	1.44	1.57	1.69	1.77	1.87	1.59
T_8. 1 ppm BR+ 150 ppm SA	0.47	0.68	0.71	0.80	0.82	0.92	0.73
T_9. T_7 + T_3	3.19	3.88	4.13	4.30	4.31	4.43	4.04
T_{10}. T_9 + T_4	1.88	2.11	2.33	2.50	2.53	2.60	2.32
T_{11}. Soil appl. micronutrients@ 5 Kg	0.68	0.88	0.99	1.10	1.11	1.22	1.00
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	2.11	2.34	2.65	2.73	2.75	2.89	2.58
Mean	1.49	1.76	1.96	2.08	2.16	2.24	1.95

Effect of chosen treatments on Peroxidase activity (Δ430 nm g^{-1} min^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	0.94	1.09	1.41	1.61	1.89	1.89	1.47
T_2. 1 % FeSO4	3.12	3.35	3.99	4.13	4.31	4.43	3.89
T_3. 1 ppm BR	0.32	0.51	0.61	0.66	0.77	0.79	0.61
T_4. 150 ppm SA	0.40	0.59	0.59	0.62	0.65	0.67	0.59
T_5. 1 %FeSO4 +0.5 %ZnSO4	2.05	2.23	2.43	2.59	2.63	2.70	2.44
T_6. 1 %FeSO4 + 0.5 % MnSO4	1.47	1.99	2.10	2.29	2.34	2.45	2.11
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	1.21	1.44	1.57	1.69	1.77	1.87	1.59
T_8. 1 ppm BR+ 150 ppm SA	0.47	0.68	0.71	0.80	0.82	0.92	0.73
T_9. T_7 + T_3	3.19	3.88	4.13	4.30	4.31	4.43	4.04
T_{10}. T_9 + T_4	1.88	2.11	2.33	2.50	2.53	2.60	2.32
T_{11}. Soil appl. micronutrients@ 5 Kg	0.68	0.88	0.99	1.10	1.11	1.22	1.00
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	2.11	2.34	2.65	2.73	2.75	2.89	2.58
Mean	1.49	1.76	1.96	2.08	2.16	2.24	1.95

Effect of chosen treatments on SOD activity- (Enzyme unit mg^{-1} protein hr^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	4.08	4.58	5.09	5.36	5.96	5.06	5.02
T_2. 1 % FeSO4	5.22	5.87	6.52	6.87	7.64	6.49	6.44
T_3. 1 ppm BR	3.38	3.80	4.23	4.45	4.95	4.20	4.17
T_4. 150 ppm SA	2.88	3.24	3.60	3.78	4.20	3.57	3.55
T_5. 1 %FeSO4 +0.5 %ZnSO4	4.87	5.47	6.08	6.39	7.10	6.04	5.99
T_6. 1 %FeSO4 + 0.5 % MnSO4	5.06	5.69	6.32	6.65	7.40	6.29	6.24
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	6.89	7.74	6.97	7.34	8.15	6.92	7.34
T_8. 1 ppm BR+150 ppm SA	3.49	3.92	4.36	4.59	5.10	4.34	4.30
T_9. T_7 + T_3	5.46	6.14	6.82	7.18	7.98	6.78	6.73
T_{10}. T_9 + T_4	5.01	5.62	6.24	6.57	7.30	6.21	6.16
T_{11}. Soil appl. micronutrients@ 5 Kg	4.35	4.89	5.43	5.72	6.35	5.39	5.36
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	4.86	5.46	6.07	6.39	7.22	6.14	6.02
Mean	4.63	5.20	5.64	5.94	6.61	5.62	5.61

Effect of chosen treatments on Fe/ Mn ratio in root

Treatment	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	116.39	113.35	108.34	112.69
T_2. 1 % FeSO4	84.21	81.93	78.12	81.42
T_3. 1 ppm BR	98.27	96.43	92.74	95.81
T_4. 150 ppm SA	95.21	93.71	91.26	93.39
T_5. 1 %FeSO4 +0.5 %ZnSO4	64.07	63.46	60.27	62.60
T_6. 1 %FeSO4 + 0.5 % MnSO4	76.20	70.22	67.34	71.25
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	66.32	63.29	60.22	63.28
T_8. 1 ppm BR+150 ppm SA	96.46	93.27	89.97	93.23
T_9. T_7 + T_3	65.24	62.32	60.42	62.66
T_{10}. T_9 + T_4	62.24	59.91	58.82	60.32
T_{11}. Soil appl. micronutrients@ 5 Kg	112.36	108.46	107.81	109.54
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	67.73	64.02	59.20	63.65
Mean	83.72	80.86	77.88	80.82

Effect of chosen treatments on Fe/Mn ratio in soil

Treatment	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	139.67	124.68	113.75	126.03
T_2. 1 % FeSO4	101.05	90.12	82.02	91.06
T_3. 1 ppm BR	117.92	106.07	97.37	107.12
T_4. 150 ppm SA	114.25	103.08	95.82	104.38
T_5. 1 %FeSO4 +0.5 %ZnSO4	76.20	69.80	63.28	69.76
T_6. 1 %FeSO4 + 0.5 % MnSO4	91.44	77.24	70.70	79.79
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	79.58	69.61	63.23	70.80
T_8. 1 ppm BR+150 ppm SA	115.75	102.59	94.46	104.26
T_9. T_7 + T_3	78.28	68.55	63.44	70.09
T_{10}. T_9 + T_4	74.68	65.9	61.76	67.44
T_{11}. Soil appl. micronutrients@ 5 Kg	134.83	119.3	113.2	122.44
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	81.27	70.42	62.16	71.28
Mean	100.41	88.94	81.76	90.37

Effect of chosen treatments on P/Fe ratio in root

Treatment	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	0.160	0.201	0.223	0.195
T_2. 1 % FeSO4	0.106	0.133	0.148	0.129
T_3. 1 ppm BR	0.166	0.208	0.232	0.202
T_4. 150 ppm SA	0.104	0.131	0.145	0.127
T_5. 1 %FeSO4 +0.5 %ZnSO4	0.109	0.137	0.153	0.133
T_6. 1 %FeSO4 + 0.5 % MnSO4	0.157	0.197	0.219	0.191
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	0.115	0.144	0.160	0.140
T_8. 1 ppm BR+150 ppm SA	0.147	0.184	0.204	0.178
T_9. T_7 + T_3	0.095	0.119	0.132	0.115
T_{10}. T_9 + T_4	0.169	0.212	0.235	0.205
T_{11}. Soil appl. micronutrients@ 5 Kg	0.170	0.213	0.237	0.207
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	0.162	0.203	0.226	0.197
Mean	0.138	0.174	0.193	0.168

Effect of chosen treatments on P/Fe ratio in soil

Treatment	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	0.192	0.221	0.234	0.216
T_2. 1 % FeSO4	0.176	0.202	0.214	0.197
T_3. 1 ppm BR	0.131	0.151	0.161	0.148
T_4. 150 ppm SA	0.204	0.234	0.249	0.229
T_5 . 1 %FeSO4 +0.5 %ZnSO4	0.199	0.229	0.243	0.224
T_6 . 1 %FeSO4 + 0.5 % MnSO4	0.188	0.217	0.230	0.212
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	0.138	0.158	0.168	0.155
T_8. 1 ppm BR+150 ppm SA	0.127	0.146	0.155	0.143
T_9 . T_7 + T_3	0.124	0.144	0.152	0.140
T_{10}. T_9 + T_4	0.202	0.233	0.247	0.227
T_{11}. Soil appl. micronutrients@ 5 Kg	0.114	0.130	0.139	0.128
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	0.194	0.223	0.237	0.218
Mean	0.166	0.191	0.202	0.186

Effect of chosen treatments on metabolically active iron content (ppm)

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	11.34	11.58	11.84	12.23	12.43	12.57	12.00
T_2. 1 % FeSO4	44.60	27.52	25.70	29.30	65.50	69.50	43.69
T_3. 1 ppm BR	18.50	19.20	22.10	20.20	24.10	25.50	21.60
T_4. 150 ppm SA	16.80	17.11	18.60	18.00	22.50	24.00	19.50
T_5 . 1 %FeSO4 +0.5 %ZnSO4	49.80	40.64	34.70	22.70	32.30	35.10	35.87
T_6 . 1 %FeSO4 + 0.5 % MnSO4	21.00	21.76	22.10	16.90	34.20	38.50	25.74
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	36.90	30.75	22.10	25.70	37.80	40.00	32.21
T_8. 1 ppm BR+ 150 ppm SA	17.10	16.20	15.80	16.50	22.90	24.20	18.78
T_9 . T_7 + T_3	38.50	37.60	43.00	45.50	46.10	48.54	43.21
T_{10}. T_9 + T_4	33.90	32.45	31.80	30.00	43.00	45.10	36.04
T_{11}. Soil appl. micronutrients@ 5 Kg	20.70	18.65	22.89	20.85	24.80	25.90	22.30
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	34.20	30.95	32.20	31.50	48.30	49.00	37.69
Mean	28.61	25.37	25.24	24.12	34.49	36.49	29.05

Effect of chosen treatments on number (lakh ha^{-1}), weight (Kg), height of millable cane (cm)

Treatments	No.of millable cane (lakh ha^{-1})	Weight of millable cane (Kg)	Height of millable cane (cm)
T_1. Control	0.95	1.10	211
T_2. 1 % $FeSO_4$	1.00	1.32	243
T_3. 1 ppm BR	0.96	1.15	222
T_4. 150 ppm SA	0.97	1.20	234
T_5. 1 %$FeSO_4$ +0.5 %$ZnSO_4$	0.98	1.23	246
T_6. 1 %$FeSO_4$ + 0.5 % $MnSO_4$	0.99	1.25	244
T_7. 1 %$FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$	1.00	1.43	250
T_8. 1 ppm BR+150 ppm SA	0.96	1.18	223
T_9. T_7 + T_3	1.03 (8.4%)	1.60 (4.5%)	275 (3%)
T_{10}. T_9 + T_4	0.99	1.27	241
T_{11}. Soil appl. micronutrients@ 5 Kg	0.98	1.21	236
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	1.00 (5%)	1.53 (3.9%)	255 (2%)
Mean	0.98	1.29	240

Effect of chosen treatments on Girth (cm), Number and Average length of internodes (cm)

Treatments	Cane girth (cm)	No. of internodes	Average length of internodes (cm)
T_1. Control	2.58	19.01	11.09
T_2. 1 % FeSO4	2.90	20.83	11.65
T_3. 1 ppm BR	2.60	20.00	11.11
T_4. 150 ppm SA	2.71	20.16	11.60
T_5. 1 %FeSO4 +0.5 %ZnSO4	2.78	20.33	12.10
T_6. 1 %FeSO4 + 0.5 % MnSO4	2.83	20.62	11.83
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	2.94	21.80	11.69
T_8. 1 ppm BR+150 ppm SA	2.64	20.10	11.09
T_9. T_7 + T_3	2.99 (1.5%)	22.00 (1.5%)	12.50 (1%)
T_{10}. T_9 + T_4	2.88	20.66	11.67
T_{11}. Soil appl. micronutrients@ 5 Kg	2.74	20.20	11.68
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	2.91 (1.2%)	20.88 (0.9%)	11.97 (0.8%)
Mean	2.79	20.55	11.67

INCREASE IN CANE GIRTH

INCREASE IN AVERAGE LENGTH OF INTERNODES

Effect of chosen treatments on Dry weight of single plant (g pl^{-1})

Treatment	55 DAP	70 DAP	90 DAP	150 DAP	210 DAP	270 DAP	Mean
T_1. Control	80.57	135.41	185.41	560.00	880.50	1050.00	481.98
T_2. 1 % FeSO4	82.53	140.71	193.75	589.50	970.60	1210.00	531.18
T_3. 1 ppm BR	79.45	136.35	187.45	569.65	897.50	1070.00	490.07
T_4. 150 ppm SA	78.65	134.65	188.45	578.65	910.35	1105.00	499.29
T_5. 1 %FeSO4 +0.5 %ZnSO4	79.25	138.75	192.15	592.35	940.35	1135.00	512.98
T_6. 1 %FeSO4 + 0.5 % MnSO4	81.25	138.45	190.45	578.45	960.70	1050.00	499.88
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	84.65	143.65	195.45	610.89	1010.00	1270.00	552.44
T_8. 1 ppm BR+150 ppm SA	81.62	137.35	186.75	585.00	901.50	1085.00	496.20
T_9. T_7 + T_3	85.75	154.35	210.45	651.49	1115.00	1410.00	604.51 (2.54%)
T_{10}. T_5 + T_4	84.31	144.25	194.75	595.00	950.60	1180.00	524.82
T_{11}. Soil appl. micronutrients@ 5 Kg	83.75	143.75	197.25	580.00	925.75	1105.00	505.92
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	80.75	146.35	201.35	625.79	1050.00	1310.00	569.04 (1.8%)
Mean	81.88	141.17	193.64	593.06	959.40	1165.00	522.36

Effect of chosen treatments on juice quality parameters

Treatments	Brix %	Sucrose % (Pol)	Purity coefficient (%)	Reducing sugars (%)	CCS (%)
T_1. Control	19.63	18.07	90.25	0.58	11.58
T_2. 1 % FeSO4	20.24	18.22	90.20	0.40	11.9
T_3. 1 ppm BR	21.11	19.04	90.19	0.46	13.14
T_4. 150 ppm SA	19.56	19.81	87.79	0.44	12.39
T_5. 1 %FeSO4 +0.5 %ZnSO4	21.10	19.44	90.06	0.47	12.85
T_6. 1 %FeSO4 + 0.5 % MnSO4	21.61	19.00	87.92	0.47	13.13
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	22.27	19.86	87.06	0.36	13.49
T_8. 1 ppm BR+150 ppm SA	21.00	16.96	80.76	0.49	13.18
T_9. T_7 + T_3	23.21 (1.8%)	21.04 (1.64%)	92.05 (1.99%)	0.37	13.90 (2%)
T_{10}. T_9 + T_4	20.34	18.73	92.08	0.50	12.25
T_{11}. Soil appl. micronutrients@ 5 Kg	21.19	19.03	89.80	0.47	10.35
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	22.81 (1.61%)	20.10 (1.12%)	92.13 (2%)	0.42	13.70 (1.84%)
Mean	21.74	19.11	89.19	0.45	12.66

Effect of chosen treatments on cane yield (t ha^{-1}), and sugar yield (t ha^{-1})

Treatments	Cane yield (t ha^{-1})	Sugar yield (t ha^{-1})
T_1. Control	60.42	7.69
T_2. 1 % FeSO4	99.40	13.10
T_3. 1 ppm BR	72.88	10.75
T_4. 150 ppm SA	76.52	11.09
T_5. 1 %FeSO4 +0.5 %ZnSO4	92.00	14.14
T_6. 1 %FeSO4 + 0.5 % MnSO4	93.11	15.05
T_7. 1 %FeSO4 + 0.5 % MnSO4 + 0.5 % ZnSO4	110.11	15.36
T_8. 1 ppm BR+150 ppm SA	74.70	9.98
T_9. T_7 + T_3	121.11	16.83
T_{10}. T_9 + T_4	96.09	11.27
T_{11}. Soil appl. micronutrients@ 5 Kg	81.88	9.63
T_{12}. T_{11}+ 1 ppm BR + 150 ppm SA	116. 55	15.47
Mean	91.23	12.53

CHLOROTIC FIELD

A FIELD VIEW OF THE EXPERIMENTAL TRIAL SHOWING SYMPTOMS OF CHLOROSIS

RECOVERED FROM CHLOROSIS

A FIELD VIEW OF THE EXPERIMENTAL TRIAL SHOWING RECOVERY FROM CHLOROSIS AFTER IMPOSING TREATMENT (T_9) i.e.,1 - 1 %FeSO4 + 0.5 % ZnSO4+ 0.5% MnSO4 + 1 ppm Brassinolide spray @ 45,60 and 75 DAP

CONCLUSION

- The tillering capacity (2.84%), economic shoot population (1.67%) and single cane dry weight (2.54 %) were significantly influenced by foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm Brasssinolide (T_9).

- The growth attributes like LAI, LAD, CGR, RGR, NAR, SLA and SLW were favorably influenced by the foliar application of micronutrients and growth regulators. But a combination of foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide had a pronounced effect on the growth attributes.

- The chlorophyll fractions, total chlorophyll content and a/b ratio were also significantly influenced.

- The net photosynthetic rate, stomatal conductance, transpiration rate, chlorophyll fluorescence, soluble protein were also influenced by foliar spray of 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm brasssinolide.

- The metabolically active fraction of iron which is considered as a correct estimate of active iron status of the plant was greatly influenced by foliar spray of 1% $FeSo_4$ followed by 1 % $FeSO_4$ + 0.5 % $MnSO_4$ + 0.5 % $ZnSO_4$ + 1 ppm Brasssinolide (T_9).

Contd…..

- **The yield components like number of millable cane, cane height, cane girth, number of internodes, and average length of internodes were positively influenced by foliar application of iron, manganese, zinc along with growth regulator brassinolide (T_9) and hence resulted in increased cane yield.**

- **The cane juice quality parameters like brix per cent, pol per cent, purity coefficient, reducing sugars and commercial cane sugar were significantly influenced by foliar application of iron, manganese, zinc along with growth regulator brassinolide**

- **Combined foliar application of iron with other micronutrients manganese, zinc as well as growth regulator brassinolide improved not only the morphological characters but also the physiological, biochemical, yield attributes and in addition to the juice quality characteristics in sugarcane.**